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MANUAL FOR RED LIGHT VIOLATION DETECTION SYSTEM

INDIAN ROADS CONGRESS
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ACRONYMS AND ABBREVIATIONS

RLVD	Red-Light Violation Detection
RLV	Red-Light Violation
OCR	Optical Character Recognition

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INTRODUCTION

The Manual has been prepared in pursuance to the first meeting of the Intelligent Transportation Systems Committee (G-7) held in September, 2021 and subsequent review meetings. As this Manual is first of its kind in IRC with an immense value towards enhancing road safety using ITS, accordingly, the work of preparation of new document on "Manual for Red Light Violation Detection System" was taken up by the Intelligent Transportation System Committee (G-7) during its tenure 2021-2023 under the convenorship of Prof. (Dr.) P.K. Sarkar. The first draft of the manual was prepared by the Sub-group comprising of Dr. Chalumuri Ravi Sekhar, Convenor of the Sub-group and Shri Sudhir Kumar, Dr. B. Anish Kini, Shri Puneet Singh Bindra and Shri Alok Sethi as members. The draft was discussed and deliberated in a number of meetings of G-7 Committee. The draft prepared by the Sub-group under the convenorship of Dr. Chalumuri Ravi Sekhar, has gone through many changes from time to time so as to arrive at consensus view.

This document is duly finalized by discussion and presentations in several meetings, and rigorous review held on the shared draft document. During the 14th meeting of G-7 Committee held on 2nd September, 2023, the draft manual was approved for submission to the GSS Committee. The list of personnel of the G-7 Committee is as under:

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The draft document was recommended by the Technical Standing Panel, appointed by the Convenor in its meeting held on 19th October, 2023. The finalized draft was placed before the General Specifications and Standards Committee (GSS) in its meeting held on 25th November, 2023 and was approved for placing before Executive Committee and IRC Council. The Executive Committee in its meeting held on 1st December, 2023 considered and approved the same for placing it before the Council. The IRC Council in its 226th Council Meeting at Gandhinagar (Gujarat) held on 2nd December, 2023 considered and approved the "Manual for Red Light Violation Detection System" for printing.

This Manual is intended to serve purpose to the ITS professionals, engineers, traffic police and various stakeholders dealing with speed enforcement measures in the road network as well as to a greater degree of road safety to all types of road users.

1 GENERAL

1.1 Background

The high proportion of fatalities on Indian roads can be attributed to various factors. One significant factor due to the heterogeneous traffic mix witnessed on the Indian roads, it is often noted that vehicles with better acceleration and deceleration capabilities often engage in over-speeding. Moreover, these vehicles also share the road with Vulnerable Road Users (VRUs) such as pedestrians, cyclists and motorcyclists. The interaction between high-speed traffic and VRUs increases the risk of road crashes and the associated fatalities and serious injury type of road crashes. Statistics published by the Ministry of Road Transport and Highways (MoRT&H), Government of India indicated an overall decrease of 10.5% in the number of road crashes over the past five years till 2021 i.e. from 2017 to 2021. However, there has been an alarming increase of 4.5% in fatal crashes and 6% in serious injury crashes during the same period. However, unfortunately the number of road crashes in 2022 increased by 11.9% compared to previous year 2021. Similarly, the number of deaths and injuries on account of road crashes increased by 9.4% and 15.3% respectively. These figures translate, on an average, into 1,264 crashes and 462 deaths every day. This suggests that whenever road crashes occur, they often result in multiple fatalities or serious injuries. In this regard, red light violations pose a significant risk on Indian roads, leading to numerous crashes, injuries and fatalities. It is of grave concern that the jumping of red light in the year 2022 had contributed to 4,021 crashes which eventually contributed to 1,462 fatalities and 3,450 serious injuries and thus translated to a percent change in 2022 over 2021 is to the tune of 82.5% road crashes 115.3% fatalities and 81.1% serious injuries (Road Accidents 2022).

To tackle this problem effectively, the implementation of Red-Light Violation Detection System (RLVDS) at the potential locations can be an effective tool to curb this menace. The implementation of a RLVDS on Indian roads offers numerous benefits that contribute to enhanced road safety, improved traffic flow, efficient enforcement and behavioral change among drivers. This article explores the significant advantages of adopting RLVDS in India, addressing the pressing need for better intersection management and road safety measures. RLVDS aim to address the serious issue of motorists disobeying red traffic signals, which poses a significant safety hazard. This violation not only constitutes a traffic offense but also jeopardizes road safety by increasing the risk of collisions with vehicles legally crossing the

intersection. Such a system utilizes advanced technology and surveillance measures to automatically capture images of vehicles that violate traffic rules. By employing Optical Character Recognition (OCR) techniques, the system can read the license plate numbers of the offending vehicles, allowing for accurate identification and enforcement.

Basically, RLVD system operates by continuously monitoring the traffic signal and activating a camera when a vehicle passes the stop line after the signal has turned red. The camera captures images of the violating vehicle, including its license plate. The collected photographic evidence is then reviewed to confirm the violation. Alerts containing the evidence, such as images and license plate information, are typically sent to the owners of the violating vehicles via mail or SMS. Enforcing red light compliance is a priority for many police departments, but it poses challenges due to various reasons. A police officer attempting to apprehend an individual vehicle for red light violation needs to have a direct view of the traffic signal. This requirement enables quick determination of whether the vehicle in question jumped the red signal or not. However, this task becomes difficult for a single officer on patrol, especially when multiple intersections and vehicles are involved.

By implementing RLVD systems, law enforcement agencies can overcome these challenges and enhance their ability to enforce red light violations effectively. The automated nature of the system ensures consistent monitoring and detection of violations, irrespective of the availability of police officers at every intersection. This technology serves as a visible deterrent, promoting compliance with traffic rules and contributing to safer driving experiences for motorists. Ultimately, the aim is to reduce road crashes, injuries, and fatalities at intersections by discouraging red light violations and holding violators accountable for their actions. This manual provides a comprehensive guide on the installation, operation, and maintenance of the RLVDS. At the policy level, RLVD manual is essential for India's urban transportation system to provide a framework for consistent implementation and adherence to traffic safety regulations. It establishes standardized guidelines for RLVD system deployment, ensuring that urban areas across the country maintain a uniform and compliant approach. Additionally, the manual aids in legal and regulatory compliance, reinforces traffic discipline, and helps urban areas align with national transportation safety objectives, ultimately creating a safer and more efficient urban transportation network.

1.2 Purpose of the Manual

The purpose of the RLVDS manual is to provide comprehensive guidelines and recommendations for the implementation and operation of red-light violation detection systems. These systems utilize advanced technology to detect and record instances where vehicles violate traffic signals by running red lights. The primary objective of the RLVD manual is to improve road safety by reducing red light violations and the associated risks of road crashes and injuries. By providing clear guidelines, the manual helps transportation authorities, traffic engineers and law enforcement agencies in planning, implementing and managing red light violation detection systems effectively. Based on the review of the studies carried out in developed countries aimed at the reduction of road crashes/deaths/serious injures using RLVD, the following are the results observed after of implementation of RLVD.

- RLVD addresses the technical specifications and performance standards that the detection systems should meet to ensure accurate and reliable operation.
- RLVD aims to deter drivers from running red lights, thereby reducing the frequency and severity of intersection crashes.
- RLVD plays a crucial role in promoting road safety, reducing traffic violations, and creating a safer environment for all road users.

1.3 Need of RLVDS

For imposition of the enforcement manually, the enforcement officers should have the same view of the traffic signal jumping red light as the violator. Officers who observe violations from cross streets or the opposing direction of traffic cannot enforce the violation. If an officer does observe a violation while viewing the same face of the traffic signal, the police officer will have to follow the violator through the flow of cross traffic that has the green signal, creating a dangerous situation for both the officer and the crossing vehicles. Alternatively, there need to be two officials wherein one noting the violation upstream and relaying the same to the other downstream for enforcement. These factors make it difficult for an officer on patrol to enforce red light violations and force officers to position themselves in a stationary spot to view violations. Heavy manpower and resources are required to enable police departments to enforce violations for a long period of time. This ITS based solution of red-light violation detection system may help reduce the accidents as it creates a sense of psychological fear among users not to violate the traffic rules. It also helps the driver to respect the law, provides visual and documentary evidence of violation, and captures regular offenders. There are three types of

systems available namely i) Inductive Loop Sensor, ii) Above Ground Sensors like Radar and iii) Microwave based sensors techniques and ANPR cameras.

Various sensors are used in practice to detect the vehicles, which violate the red-light rule. Microwave and optical sensors may cause false triggering of the camera due to non-vehicle objects which may pass over the stop line. Magnetic loop and fibre-optic sensors are more reliable in detecting vehicles; however, they are also avoided because of destruction caused on the asphalt and interruption of traffic during their installation. To eliminate the adverse effects of vehicle sensors, image processing techniques are used in new systems, to detect vehicles and take pictures of vehicles violating the red-light rule using only a single camera. Vehicle detection using image processing is based on comparison of the current picture frame to the previous one, known as frame differencing. Automation of traffic violation detection would help in improved management. Using readily available vehicle detection and camera surveillance technology, it is now possible to automate this type of enforcement.

Several factors that contribute to crashes caused by Red-light violation have been identified from research and crash data studies. These factors include: Driver behaviour, Intersection design and operation, Vehicle characteristics and Weather.

Driver behaviour is the most significant contributing factor to the occurrence of Red-light violation. Majority of the accidents at the intersection are related to driver decision at the dilemma zone. Dilemma zone is the region on an intersection approach where driver is presented with a condition (amber signal indication) upon which a decision has to be taken, whether to stop before the stop line or pass through. Motorists may accelerate when anticipating a change in signal indication, to make it through the intersection during amber. If a motorist misjudges the time of the signal change, he or she will enter the intersection during the red signal. Motorists driving above the posted speed limit or driving too fast would increase the distance needed to stop before entering the intersection and decrease the distance available to react to a change in traffic signal. In other words, speeding significantly increases the risk of running a red light which in turn increases the possibility of being involved in a crash. For many drivers, inattentiveness may also be the contributing cause. Drowsiness, conversing with passengers, attending to children, eating and use of a cellular phone or other electronic devices are among the many common distractions that cause drivers to reduce their focus on the task of driving. Inattentive or distracted drivers may perceive a change in signal indication late or

in some cases not at all. Motorists, perceiving the signal indication late are at a risk of jumping the red signal.

Intersection Design and Operation: Deficiencies in the design and configuration of signalized intersections may contribute to red light violations. Certain design and configuration conditions (geometrics) may provide inadequate stopping distance, may cause motorist to be confused, or limit visibility of traffic control devices. Where these design and configuration conditions can be identified and corrected through engineering improvements, the number of red-light violations can be reduced. Therefore, it is important when considering the use of a red-light camera system that an engineering study be done to identify potential engineering improvements that could be implemented in the intersection design and configuration. If an engineering study identifies countermeasures that might take considerable time to design and implement, then appropriate operational guidelines to short-term temporary solutions should be considered while long-term improvements are investigated and implemented. Engineering related parameters that contribute to Red-light Violation by motorists are as following:

a) Gradient
b) Poor Visibility
c) Roadside obstructions
d) Line of Sight
e) Traffic Volume
f) Signal Timing

To make informed decisions, authorities often rely on a combination of crash data and red light violation data. These two sets of information are crucial for assessing the safety performance of an intersection. Historical crash data helps identify intersections with a higher frequency of accidents, especially those involving red light violations. This information helps prioritize intersections in need of safety improvements. Whereas monitoring violations can reveal patterns of non-compliance with traffic signals. Intersections with consistently high red light violations may require attention even if crash data doesn't indicate a significant problem yet. In addition to these data, other factors can influence decisions, these includes Traffic Volume and Patterns, Budget and Resources, Community Feedback

Ultimately, the final decision should be based on a holistic evaluation that combines crash data, red light violation data, and various contextual factors to ensure that resources are allocated effectively to enhance intersection safety.

1.4 Scope of the Manual

The scope of this manual is limited to the RLVDS, the specification that must be used for implementation of RLVDS. The manual discusses the functional part of this system in terms of placement of the red-light violation detection system, the components of a red-light violation detection system, and the suggested minimum specifications for the red-light violation detection system. The manual further discusses the benefits and the limitations of the system. The manual also presents some sample placement of the red-light violation detection system.

1.5 Who Should use RLVDS

The RLVD manual is intended to be used by a variety of stakeholders involved in the planning, implementation, operation, and maintenance of red light violation detection systems. These stakeholders include:

Transportation Authorities: Government agencies responsible for transportation and road safety, such as transportation departments or ministries, can utilize the RLVD manual

Traffic Engineers: Professionals involved in the design and engineering of road infrastructure, traffic signal systems and intersections can benefit from the RLVD manual.

Law Enforcement Agencies: Police departments and other law enforcement agencies responsible for enforcing traffic laws can use the RLVD manual to understand the operational aspects of red light violation detection systems, including camera placement, data management, and legal considerations.

Researchers and Academics: Individuals and institutions conducting research in the field of transportation and road safety can use the RLVD manual as a reference for studying the effectiveness and impact of red light violation detection systems.

1.6 Legal Aspects of RLVD

The Motor Vehicle Act (Amendment) Bill, issued in 2019 provides the legal backing for implementation of this ITS based system to ensure a greater degree of safety to the road users. Under this act section 115 of the Act allows for the installation of automated traffic enforcement systems, including RLVD systems. RLVD systems generate photographic or video evidence of red light violations. This evidence is admissible in court and can be used for legal proceedings against the violators. However, it is essential to ensure that the RLVD systems comply with the prescribed technical standards and procedures to maintain the

integrity and authenticity of the evidence. Light violations captured by RLVD systems attract penalties and fines as prescribed under the Motor Vehicles Act.

RLVD systems involve the collection and processing of personal data, such as vehicle registration numbers and images of drivers. It is crucial for the implementing authorities to adhere to applicable data privacy and protection laws, such as the Information Technology. RLVD systems may face legal challenges related to their accuracy, calibration, and adherence to prescribed guidelines. It is essential for the implementing authorities to ensure that the systems are regularly calibrated and meet the technical standards specified by the law. Traffic rules and enforcement can vary between different states and union territories in India. While RLVD systems are generally permitted, it is important to review the specific laws and regulations of the relevant jurisdiction to ensure compliance.

2 DEFINITION OF RED-LIGHT VIOLATION AND ITS EFFECTS

2.1 Definition of Red-Light Violation Related Terminologies

There are various definitions of the Red Light Violation Detection (RLVD) system found in the literature. Here are some compiled definitions:

- According to Ruby and Hobeika (2003) in their study on Virginia City, a violator of a red light is defined as a vehicle traveling at a speed greater than 18 kmph if the speed limit is less than 45 kmph, and greater than 20 kmph otherwise. Additionally, the vehicle must cross the stop line after the signal has turned red for more than 0.2 seconds.
- Retting et al. (1999a; 1999b) proposed a definition for RLVD enforcement in California and Virginia. They defined a Red Light Violator (RLV) as a vehicle traveling at least 15 mph (miles per hour) that enters a signalized intersection after the signal has turned red for up to 0.4 seconds.
- In a study conducted by Retting et al. (1998), they defined an RLV as a vehicle approaching an intersection at a high speed (at least 15 mph) and entering the intersection when the signal turns red.

Considering the traffic situations in India, RLVD systems should be specifically designed to effectively monitor traffic intersections. These systems automatically capture images of vehicles that pass the stop line when the traffic light is red. The RLVD system captures images of the rear side of vehicles, including their license plate numbers, and uses Optical Character Recognition (OCR) to convert the images into text format. The system continuously monitors the traffic signal, and the camera is triggered when any vehicle passes over the stop line for a duration of 1 second after the signal has turned red.

In the Indian context, RLVD refers to the identification and monitoring of vehicles that cross the stop line at an intersection after the traffic signal has turned for more than 0.5 seconds, without considering the vehicle's speed. This definition emphasizes the time threshold of 0.5 seconds from when the signal changes to red, rather than taking into account how fast the vehicle is moving. However, a common approach is to allow a tolerance of around 0.5 seconds beyond the actual onset of the red signal. This means that if a vehicle crosses or touches the stop line within the first half seconds after the red light appears, it is generally not considered a violation. This allowance accommodates factors like driver reaction time and ensures that minor infractions due to abrupt stops or road conditions do not result in unnecessary enforcement actions. The specific time tolerance can vary based on local traffic regulations and engineering assessments.

2.2 Effects of Red-Light Violation Devices

The presence of RLVD in the system creates a sense of fear among the travellers and therefore imparts safe passage and proper enforcement. Various studies have taken place at many locations where the camera type red light violation detection systems have been installed and their impact has been noted. The effects of implementation of these devices are depicted in **Table 1**. The benefits outlined in the **Table 1** stem from a comprehensive review of various existing literature sources.

Table 1 Effect of Implementation of RLVD in different parts of the World

City	Sites of Installed Cameras	Type of Crash	Effects of Installed Camera
Sydney, Australia, Hillier, et al. (1993)	16 intersections	Right-angled and left turn opposed	Reduction of 50%
Glasgow, Scotland Winn (1995)	6 sites	Injurious collision caused by red light violators	Reduction of 62%
Different cities of England and Wales Hooke, et al. (1996)	78 intersections	Preferred for all injuries	Reduction of 18%
Singapore Ng, et al. (1997)	42 intersections	All injuries	Reduction of 7%
		Right angle	Reduction of 8%
San Francisco, California Fleck, and Smith (1998)	6 intersections	Crash due to red light violators	Reduction of 9%
Mesa, Arizona Vinzant and Tatro (1999)	6 intersections with RLC only, 6 intersections with RLC and photo speed enforcement	Combined treatment section	Reduction of almost 16%
		RLC circuit section resistor (R), an inductor (L), and a capacitor (C)	Reduction of 9.7%
		Photo-radar section	Reduction of 7.5%
		Control section	Reduction of 10.7%
Howard Country, Maryland House of Delegates (2001)	25 intersections	Rear end	Reduction of 32%
		Right angle	Reduction of 42%
		Other	Reduction of 22%

(Source: Amalgamating insights and findings from multiple studies)

2.3 Warrants Supported by Scientific findings from the Literature

Warrants supported by scientific findings from the literature play a crucial role in justifying the installation of Red Light Violation Detection Systems (RLVDS). Here are key warrants:

Safety Enhancement: Scientific studies such as that by Retting et al. (2017) demonstrate that red-light violations significantly contribute to intersection accidents. These findings warrant the installation of RLVDS, as they emphasize the potential to improve road safety by deterring red-light runners (Retting et al., 2017).

Traffic Flow Optimization: Research by Zhao and Bai (2019) highlights that RLVDS technology can lead to smoother traffic flow by discouraging violations and enhancing intersection efficiency.

Efficacy of Deterrence: Controlled studies, as conducted by Miaou (2000), prove the effectiveness of RLVDS in deterring red-light violations, providing a warrant for its installation as a preventive measure (Miaou, 2000).

Accurate Enforcement: Literature, such as the work of Wong et al. (2015), confirming the accuracy and reliability of RLVDS in capturing violations helps establish its credibility. This warrant ensures that the system's enforcement actions are based on sound and fair evidence

Economic Benefits: Studies like that of Mounce and Richard (2018) indicate reduced accident-related costs and improved traffic management due to RLVDS. This literature highlights the economic advantages of the system, further warranting its installation.

Citing these scientific findings from the literature makes a compelling case for RLVDS installation, emphasizing its role in enhancing safety, traffic flow, deterrence, accuracy, and economic efficiency at intersections.

3 DATA COLLECTION METHODS

3.1 Introduction

The primary objective of RLVD should be to determine, from available information, what impact RLVD camera enforcement has had on crashes and their related severity. This impact was to be identified for intersections where a camera(s) had been installed and, if possible, area wide within the jurisdiction or district. Furthermore, it was important to identify factors viz. geometry, operations, signage, public outreach, and others that influence the observed changes. As part of this crash analysis, there can be a supplementary objective of reporting how crash analyses were and are to be conducted and which findings could be used as guidance for other evaluations.

3.2 Data Collection Methods

As per literature, there are many types of methods available for collection of red-light violation data, some of them are Infrared, Sensing Technologies, Inductive Loop Detection, and Various Sensor Less Technologies etc. Some of the popular data collection methods used are presented below:

Infrared: It is a wireless technology used in devices or systems that transfer data through infrared (IR) radiation. Infrared is electromagnetic energy at a wavelength or wavelengths somewhat longer than those of red light. The operation is more or less similar to RFID. It works with passive working mechanism with electric sensor that measures IR light radiating from all objects with temperature above absolute zero. It means that a Passive Infra-Red (PIR) device does not generate or radiate any energy for detection purposes. In this case, IR light is being generated from vehicles plying on the road. It can classify vehicles along with estimating the speed and density of vehicles. It is easy to install with high probability of detection along with good resistance to rain, fog, dust, and snow.

Sensing Technologies: Sensing systems for Intelligent Transportation System are vehicle and infrastructure based networked systems, e.g., intelligent vehicle technologies. Pavement loops are used to sense the presence of vehicle demand at intersections and parking lot entrances. Pressure pads are used to sense the presence of pedestrians waiting to cross a roadway.

Inductive Loop Detection: One or more loops of wire are embedded under the road and connected to a control box. It is an established technology and not impacted by environmental conditions. Accurate in detecting vehicle presence and also performs well in both high and low volume traffic. A set-up of inductive loop detection system is shown in **Fig.1**.

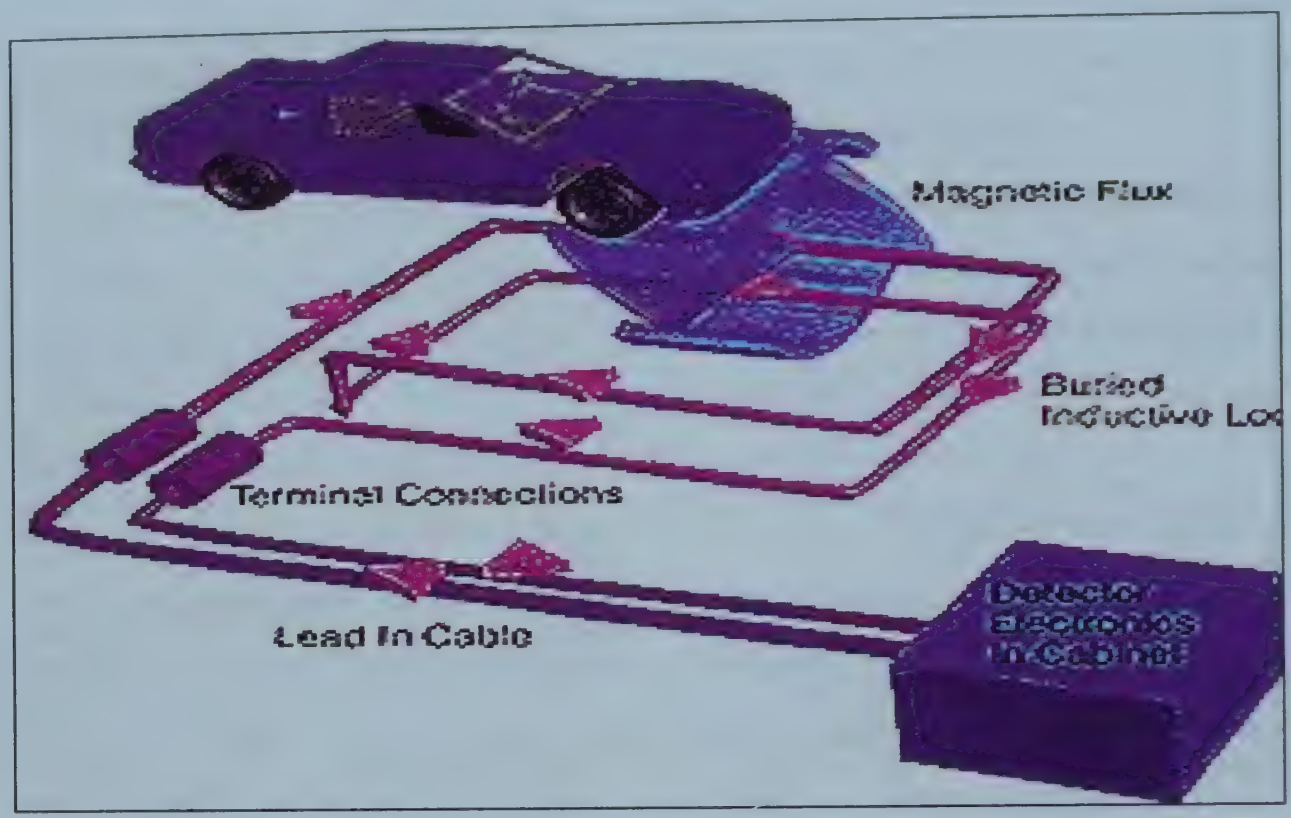

Fig.1 Inductive Loop Detection System (FHWA, 1998)

Sensorless Technology (Using Image Processing): The key point in the operation of the new system as illustrated in **Fig. 2** is to detect the presence of a vehicle that crosses the violation line while the red light is on, by applying image processing techniques on the picture frames which are received continuously from a camera observing the violation region. Once the vehicle is detected it can be tracked through the video frames for taking the picture of its license plate. There are two major problems associated with vehicle detection using image processing which may result in false triggering of the camera. One of these problems arises when a non-vehicle object such as a bird or a pedestrian who may cross the borderline while the vehicle is waiting at the red light. To avoid false triggering due to changes in daylight, the interface difference technique is used, where each frame is subtracted from the previous one to determine the changed regions. Moreover, the number of changing pixels along the violation line is compared with a critical value to differentiate between the vehicles and other objects. The system setup is illustrated in **Fig. 2**, where a video camera is mounted on top of a pole located at one side of the road, where the violation line is designated at a location just after the signal head post. Frame differencing in temporal domain and threshold techniques are used to detect

the existence of a vehicle. A difference frame is obtained by subtracting the previous frame from the current frame and a binary image of the difference frame is obtained by using threshold method. The number of changing pixels along the violation line on the binary image is calculated at each refresh cycle and compared with a critical value, which allows the program to differentiate between the vehicles and other objects. When the number of pixel sum along the violation line exceeds the critical value, while the red light is on, it is assumed that a vehicle is violating the red-light rule. A triggering pulse is thus produced to trigger the camera and capture the picture of the vehicle on which its licence plate can be seen clearly.

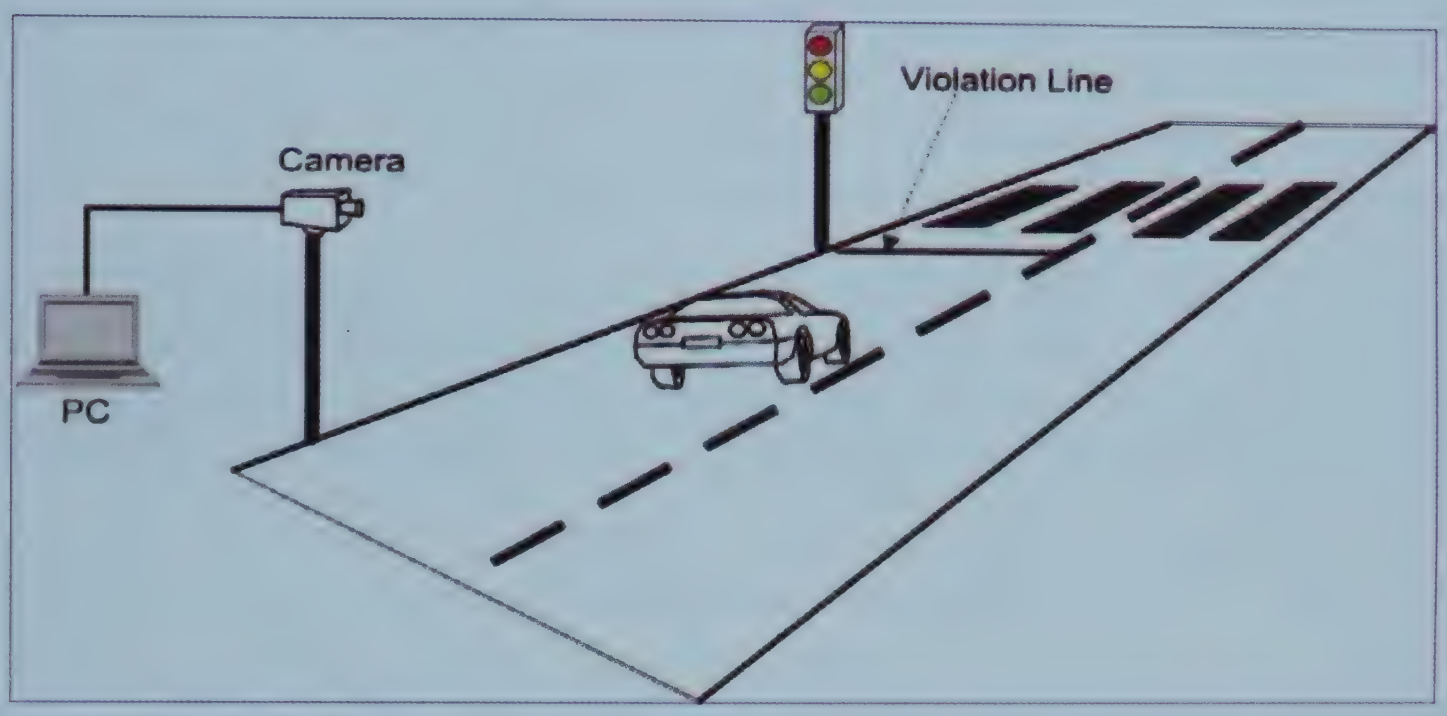

Fig. 2 Violation Detection using Cameras (Image Processing)

To avoid the destructive nature of vehicle detectors, such as magnetic loop and fibre optics, and the false triggering nature of microwave and optical sensors, a novel sensor less Red-Light Violation Detection System is to be used. The existence of a vehicle passing the red-light violation line is detected by continuously checking whether there is a change in pixels along the violation line. The on state of red light is also detected by checking the changes in pixels at the location of the red-light. Performance of the proposed system is compared with reference to a magnetic-loop-detector based Red Light Detection System, where it is observed that the rate of false triggering was below 1%, which proves the validity of the proposed system. As this system uses nothing more than a single camera, its cost is much lower than those which utilise specialised vehicle detectors.

3.3 Brief Comparison of Various Techniques of Data Collection

Table 2 shows the advantages and disadvantages of various methods of data collection.

Table 2 Brief Comparison of Various Data Collection Techniques

S.No.	Method	Advantage	Disadvantages
1	Infrared Method	Provides detailed information about the vehicle, the trajectory, and the speed of the vehicle.	The method uses tags to identify different vehicles and the infrared cables must be laid under the pavement surfaces thereby drastically reducing the lifespan of the pavement.
2	Sensing Technologies	The method uses magnetic rays and pressure pads, which give the most accurate data of the vehicle and the pedestrian movement	The installation, commissioning, operation, maintenance, and enforcement from this method is very-very difficult and expensive
3	Inductive Loop Detection System	The sensor wires work very well in high and low traffic conditions, give accurate data on the traffic volume	False trigger and identification of vehicle for enforcement purpose is difficult, Pavement overlays impact its effectiveness
4	Sensor Less Technology	This technology does not require the road to be closed, no chances of false triggering, as the evidence would be presented along the fine, no effect on the pavement health, low maintenance as compared to the other methods	The cameras are exposed to extreme weather conditions, the cameras have a limited visibility, and the cameras can sometimes be dodged by either changing lanes, or by giving dipper on the cameras so that the image evidence may not be properly legible, hence saving driver from fines.

Based on the above comparison and on basis of the Indian experience, the sensor less technology is best suited for the Indian subcontinent. More details about sensor less technology is presented in further sections. Use of sensor less AI driven Technology is considering one of the best approach due to advance technology and alogorithms Red-light violation helping to capture the data at higher accuracy to analyse and controlling accidents situations also it is reducing manpower efforts for investigations and quickly locate the meaningful data.

4 SPECIFICATIONS OF RLVD

4.1 Introduction

This section deals with the specification of the RLVD system, firstly the components of RLVD system, followed by a brief overview of working and placement of the system, lastly followed by the specification of the system.

4.2 Components of RLVD

The specification of RLVD is almost same as that of the ANPR devices. The RLVD consists of an ANPR camera, Evidence / Overview camera, IR Illuminator, Local Processing Unit (LPU) the whole system being mounted on a pole and installed near the stop line of various arms of the intersections. The detailed architecture of the system is presented in forthcoming sections.

4.3 Working of RLVD

The field unit comprises of the ANPR cameras, the scene cameras and a local processing unit calibrated to the signal at the arm of the intersection. RLVD solution shall have an overview camera to capture the zoomed-out picture of the entire area when there is a red-light violation. Light sensors shall be placed to detect the change in traffic light. Once the traffic light has turned red, the sensors shall activate the camera to capture images of the vehicles that jumped the traffic light, the local processing unit, both the scene camera (also known as the overview camera) and the ANPR camera. The images along with some data such as image of the vehicle, image of the number plate, text conversion of number plate after OCR, offence date, time of offence and location of offence (including carriageway, location plying from and towards location), the exact status of the traffic signal at the instant of violation, and speed violation detection are then fed to the local processing unit. The unit through the image processing algorithms detects the violating vehicles and detect their registration numbers (as received from the ANPR camera) and issue fines. This whole process takes time depending on various internal and external factors such as internet speed, the traffic, time taken for evaluation, the no. of arms, no. of junctions under one central unit etc. **Figs. 3 to 5** illustrate the working and the detailed architecture of the RLVD system. **Fig. 6** shows an architecture of the system.

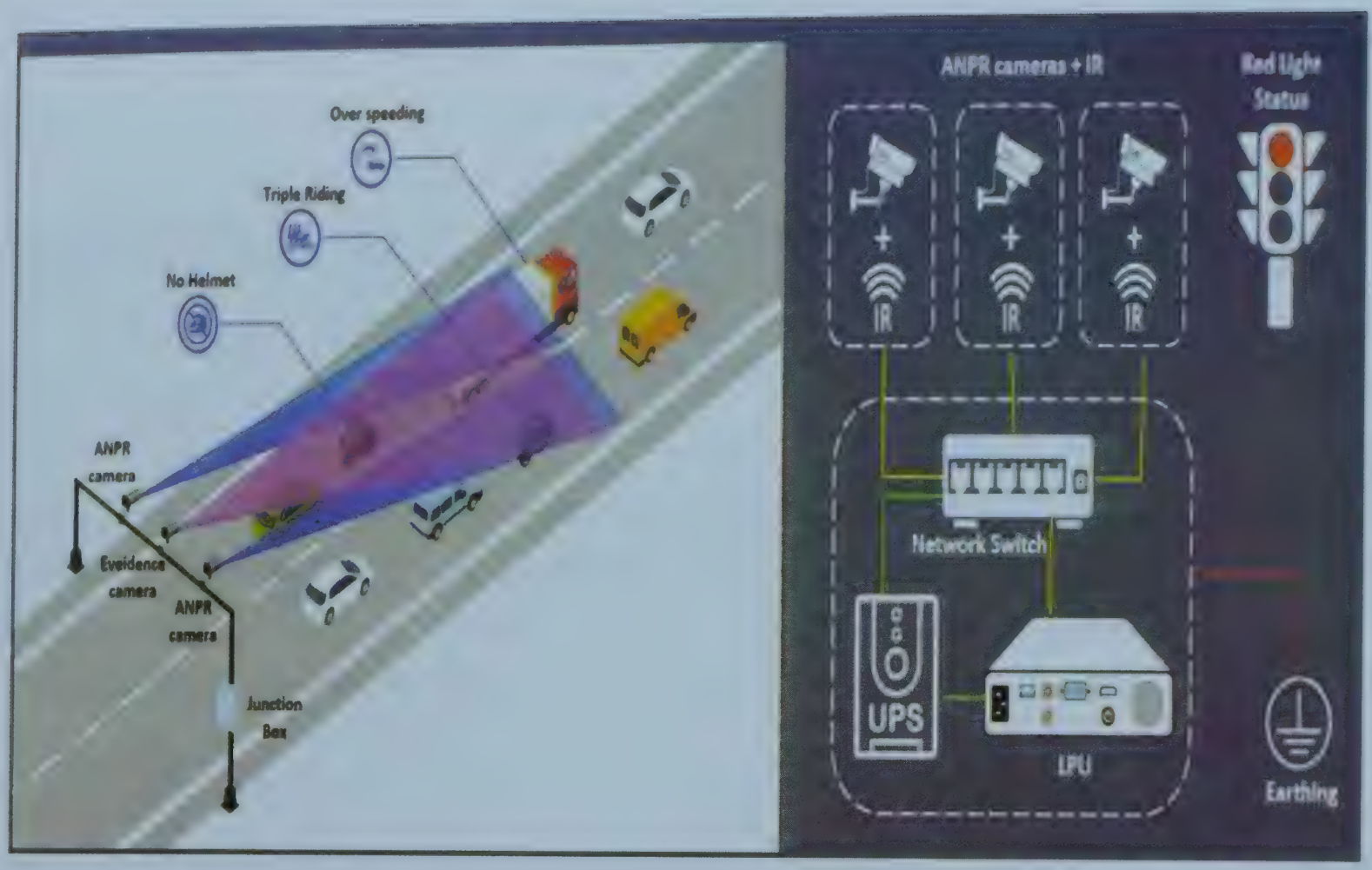

Fig. 3 Detection of Violation by RLVD System at Midblock

Fig. 4 Detection of Violation by RLVD System at Intersection

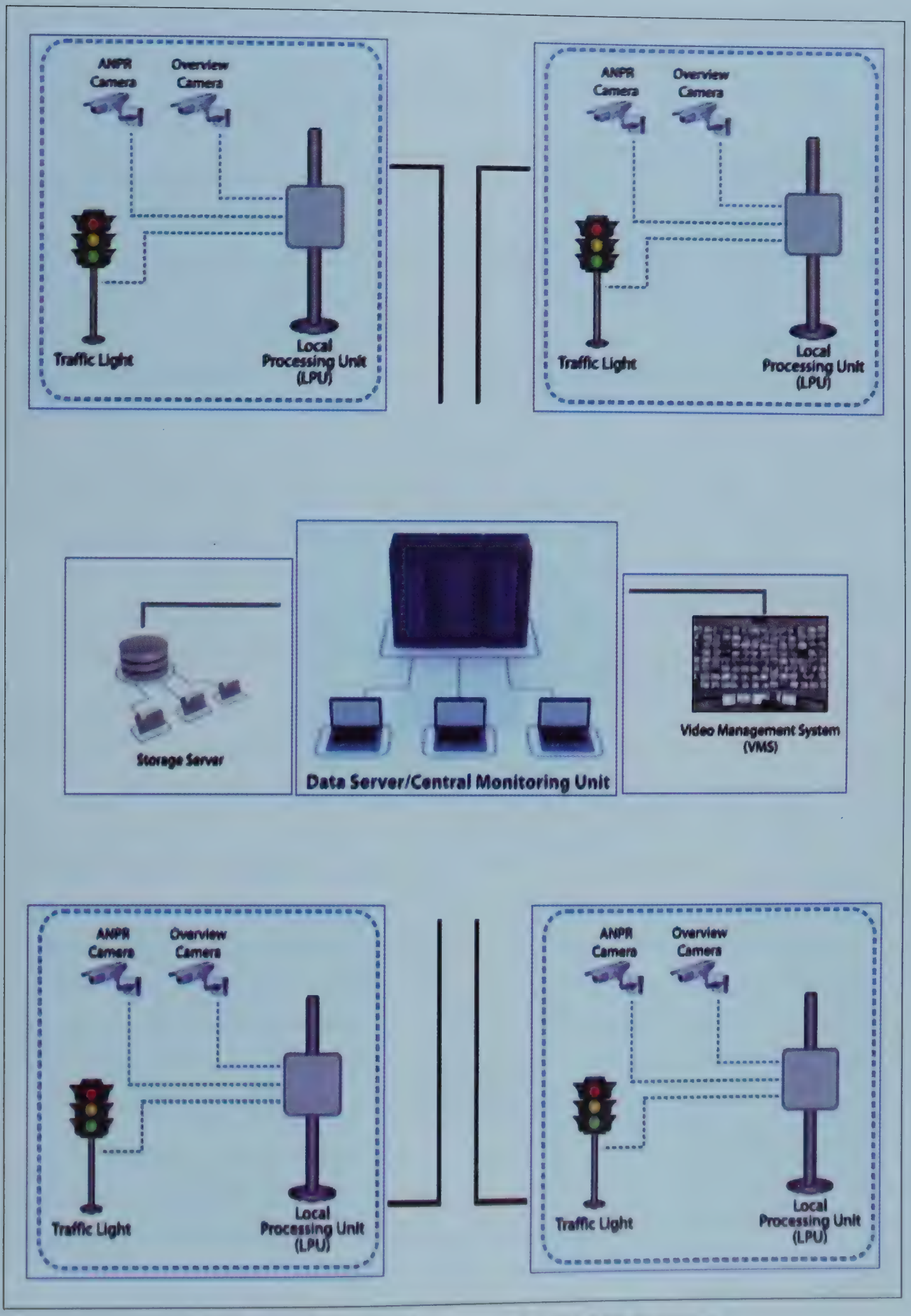

Fig. 5 Detailed Architecture of a RLVD System

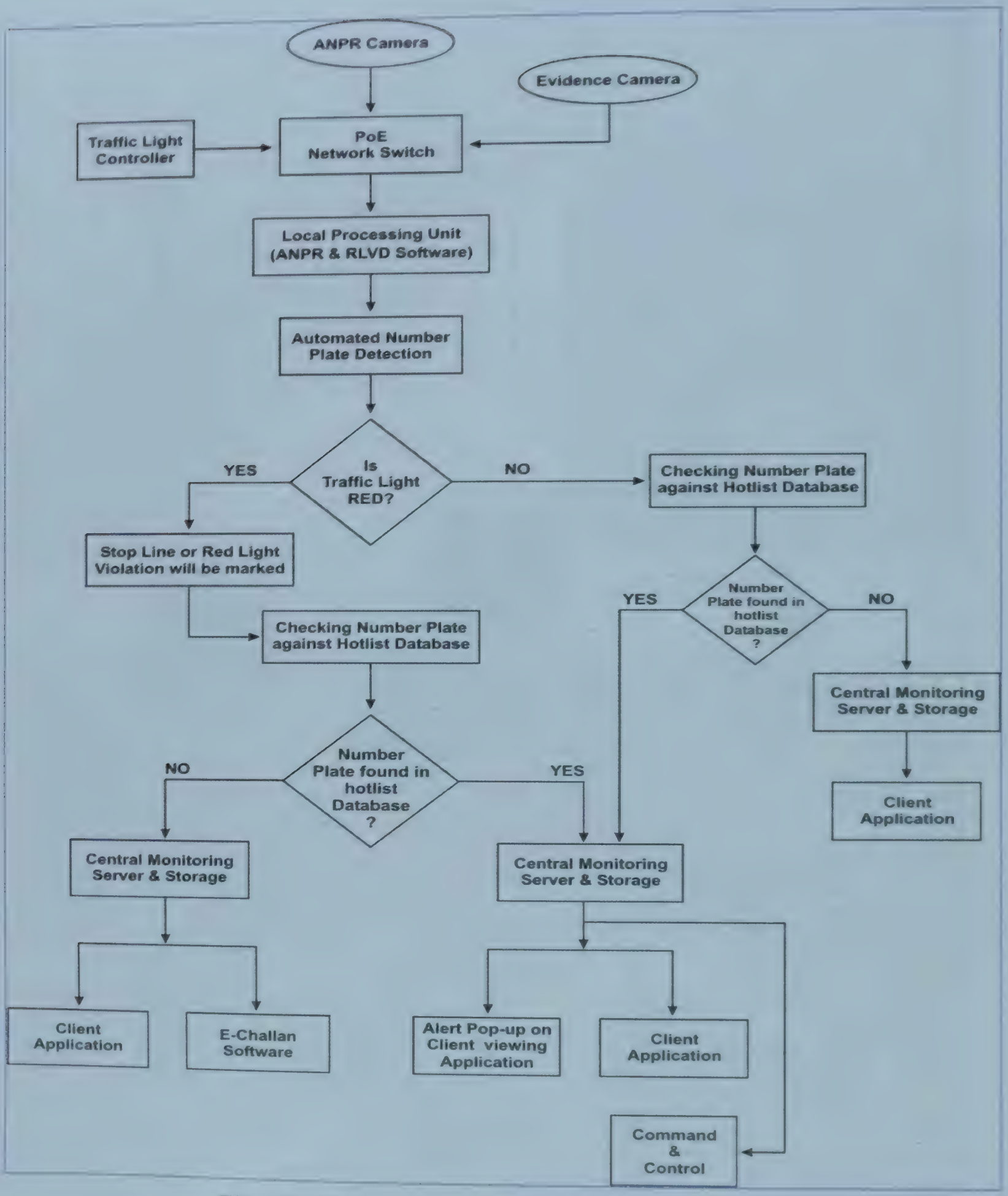

Fig. 6 Detailed Process Flow of a RLVD System

4.4 Placement / Design Guidelines of RLVD System

The placement of RLVD system depends on the available space, the headroom for the system, the distance of the camera from the stop line, the availability of clear view, the sunlight and glare effects on the system. Ideal placement of the system components is as mentioned below:

Junction Setup: Each junction at pre-identified location for all Violation locations / Junctions for installing traffic violation cameras will have cameras installed as explained above. ANPR cameras will be mounted on a cantilever / gantry at a height of 6 - 6.5 m. These ANPR cameras will be associated with evidence cameras to be used for RLVD + Stop-Line purpose. An Industrial grade Local Processing Unit must be used to Protect the unit from shock, vibrations, weather conditions, LPU will connect the junction cameras at the pre-identified location of the junction itself. The cameras and IR illuminators to be mounted on cantilever / gantry, specially installed for this purpose. All the cameras and the LPU are to be powered through an UPS. A network switch will be required to connect the cameras and the LPU over LAN. A router will also be required to connect to the WAN network. The poles should be at least 6 to 7 m high, the maximum distance from the stop line to the base of the pole should be 13-18 m and the rear-view camera should be 15 m behind the start of the pedestrian crossing. Some typical views on placement are shown in **Fig. 7**.

Camera Placement / Camera & Mounting Cantilever / Gantry Requirements: The placement of camera mainly depends on the available space, the headroom available and the camera focal range among others. Cantilever / Gantry is to be constructed and erected so that there is no vibration of cantilever / gantry during windy weather, resulting in vibration of cameras. Required ear thing should be done. The cameras are to be mounted on the arms of the cantilever / gantry in such a way so that the each lane should be covered. ANPR camera installation guidelines must be followed for proper functioning of the system. System Integrator to ensure that selected ISPs provides network uptime and QOS in such a way that the LPU data is getting transmitted in a seamless manner. To handle network outage issues, the proposed system architecture provides local storage of events at each junction level. However, this is limited to the amount of storage provisioned at each junction level **(Table 3)**.

Front-side cameras capture the vehicle's approach and signal compliance, while rear-side cameras record violations as vehicles clear the intersection. The placement of RLVD cameras on the front or rear side of an intersection should consider several key criteria:

- Line of Sight
- Distance from Stop Line

- Camera Angle
- Illumination
- Secure Mounting
- Maintenance Accessibility

The choice of front or rear placement depends on the specific enforcement goals and legal requirements of the jurisdiction, but ensuring visibility and compliance with local regulations are paramount.

For optimal placement, it's recommended to install the camera atop an overhead gantry alongside the traffic signal. The ideal system involves a non-intrusive setup where the signal is seamlessly integrated as part of the entire system.

Table 3 Camera Placement Types and Specifications

Sl No	Type of Placement	Description	Specification	Advantages	Dis-advantages
1	Overhead	The camera is placed directly above the lane and captures the vehicle image from the front-Top angle.	**Height of Camera: Range:** 5 to 10 m above road FRL. **Angle of Camera:** 25 to 45 degrees downward from the FRL. **Range of the Camera:** maximum at 35 m in the line of sight of the camera	The image is crisp, the data is highly accurate. Glare effect of vehicles is removed. The camera can clearly fetch the driver and passenger details.	An overhead gantry is required for placement of the cameras, a single camera covers a single lane.
2	Transverse	These cameras are placed on the sides/ kerbs of the roadside, and they catch the data from an angle.	**Height : Range:** 3 to 12 m from the FRL. **Offset of the Pole:** 1 to 2 m from the road edge. **Vertical Rotation:** 25 to 45 degrees downwards. **Range of Camera:** Along line of sight is around 10 to 30 m	These cameras can be used as surveillance cameras too, the installation of these cameras is easiest.	These cameras are prone to glare, and they are unable to capture the full detail of the vehicle.

Fig. 8 to 14 show some good practices to be followed while deciding the placement of the camera.

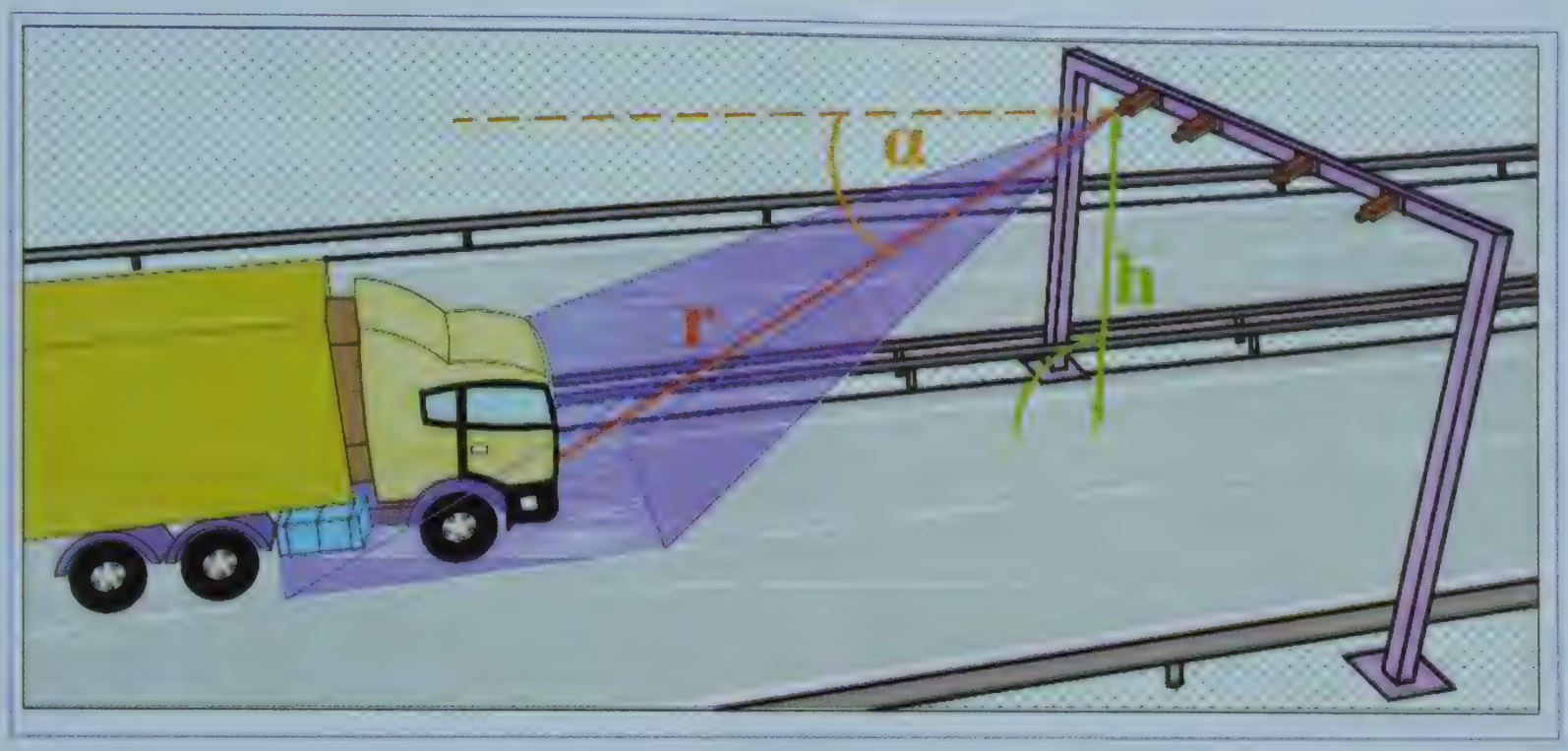

Fig. 7 Camera Placement Parameters

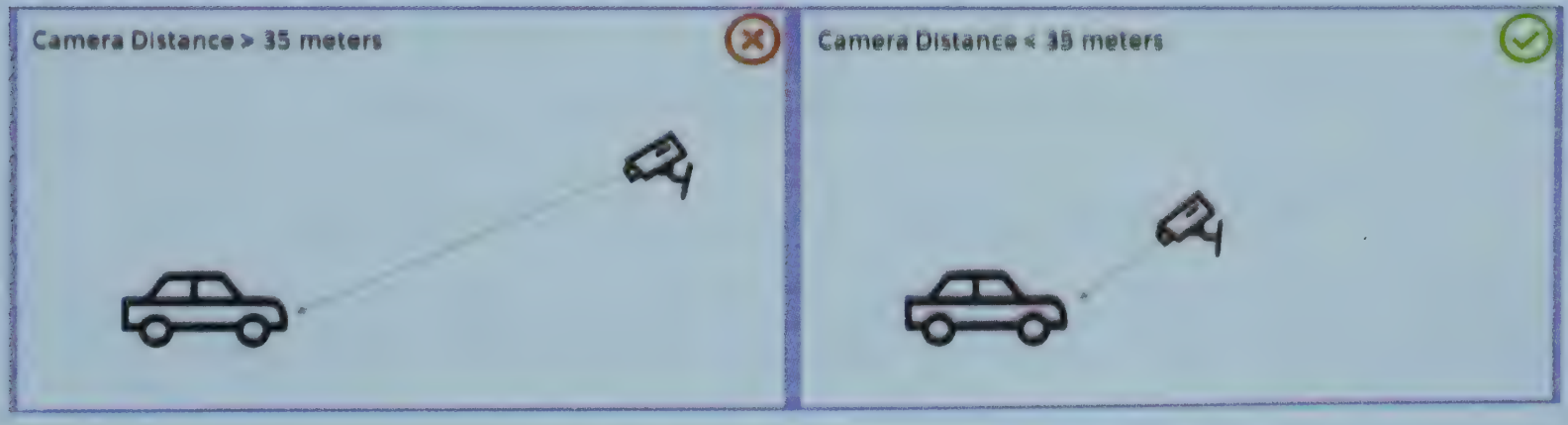

Fig. 8 Camera Distance

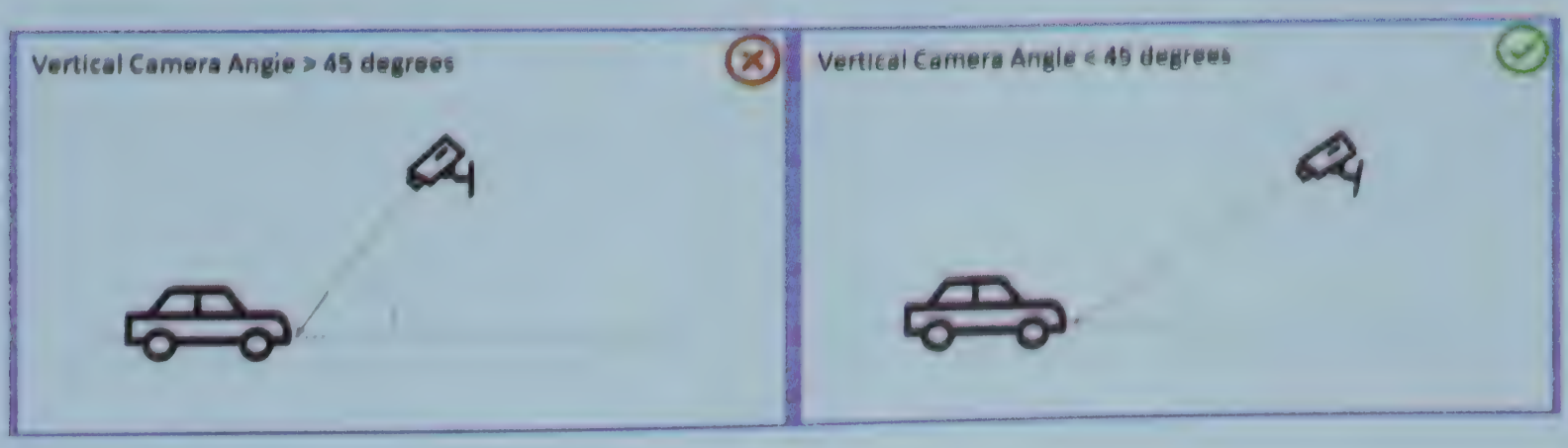

Fig. 9 Vertical Camera Angle

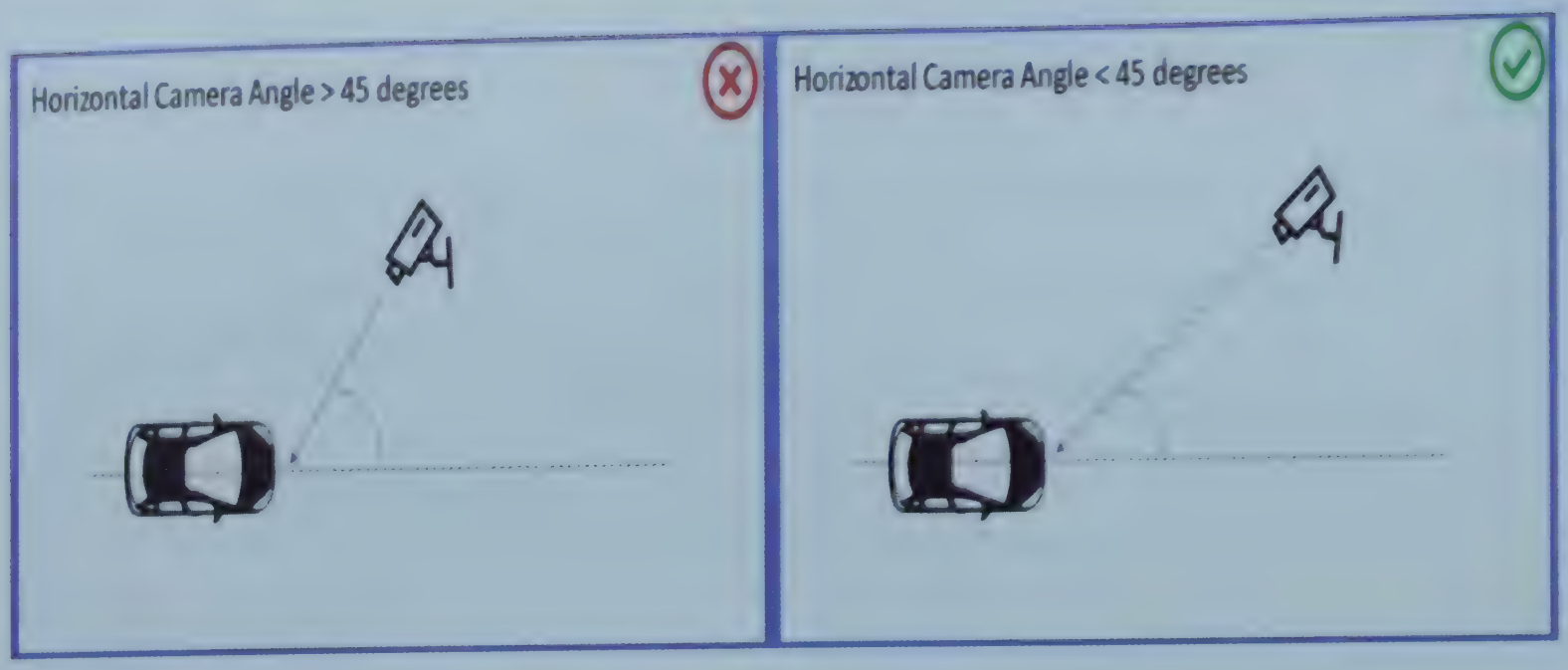

Fig. 10 Horizontal Camera Angle

The maximum distance from an RLVD camera to a vehicle's license plate is typically influenced by camera resolution and image clarity. Higher resolution cameras, like 2 MP (2 Megapixels) or higher, allow for longer capture distances. For cameras with resolutions below 2 MP, maintaining optimal plate readability within 15 m is recommended, while 2 MP or higher resolution cameras can extend this distance up to 25 m decision-making factors include local traffic conditions, camera quality and enforcement requirements. These guidelines are often defined by traffic enforcement authorities and camera manufacturers.

Maximum Distance (Feet's) from Camera to Vehicle Plate				
Camera Megapixel (Resolution)	**USA**	**Europe**	**Brazil**	**India**
2 MP (1920 x 1080)	24.0	14.1	18.3	50 feet/15 m
4 MP (2688 x 1520)	33.6	19.7	25.6	75 feet/25 m
6 MP (2816 x 2112)	35.2	20.6	26.8	75 feet/25 m
8 MP (3264 x 2448)	40.8	23.9	31.1	75 feet/25 m
10 MP (3648 x 2736)	45.6	26.7	34.8	75 feet/25 m

To be considered for Red - Light Violation Detection (RLVD), a camera must meet a minimum quality standard of 2 Megapixel (2 MP).

Placement of RLVD system: as per the road conditions

i) Front Placement of Camera

a) 4 - Legged Intersection

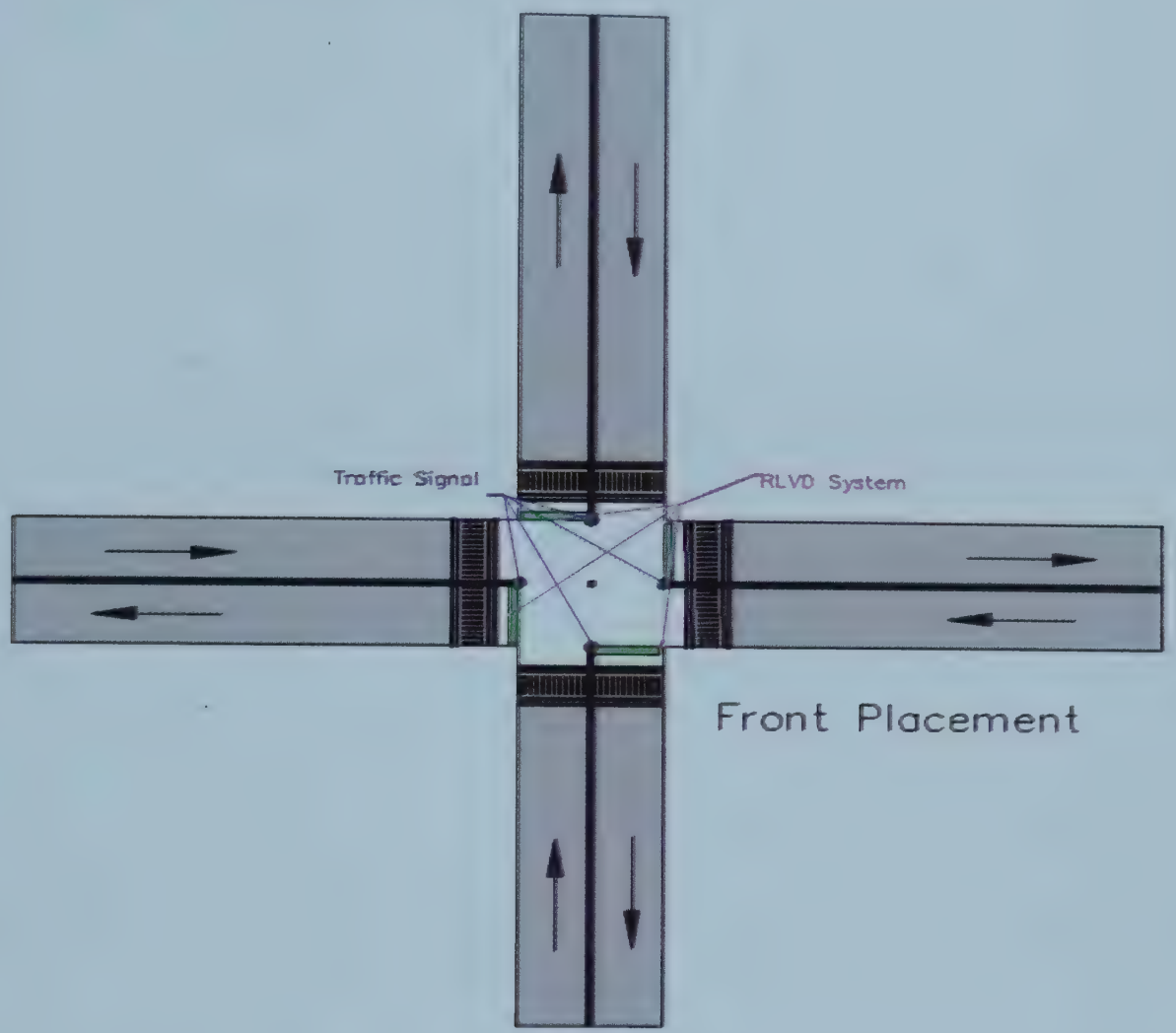

Fig. 11 The Front Placement of RLVD Devices in 4 - Legged Intersection

b) 3 - Legged Intersection

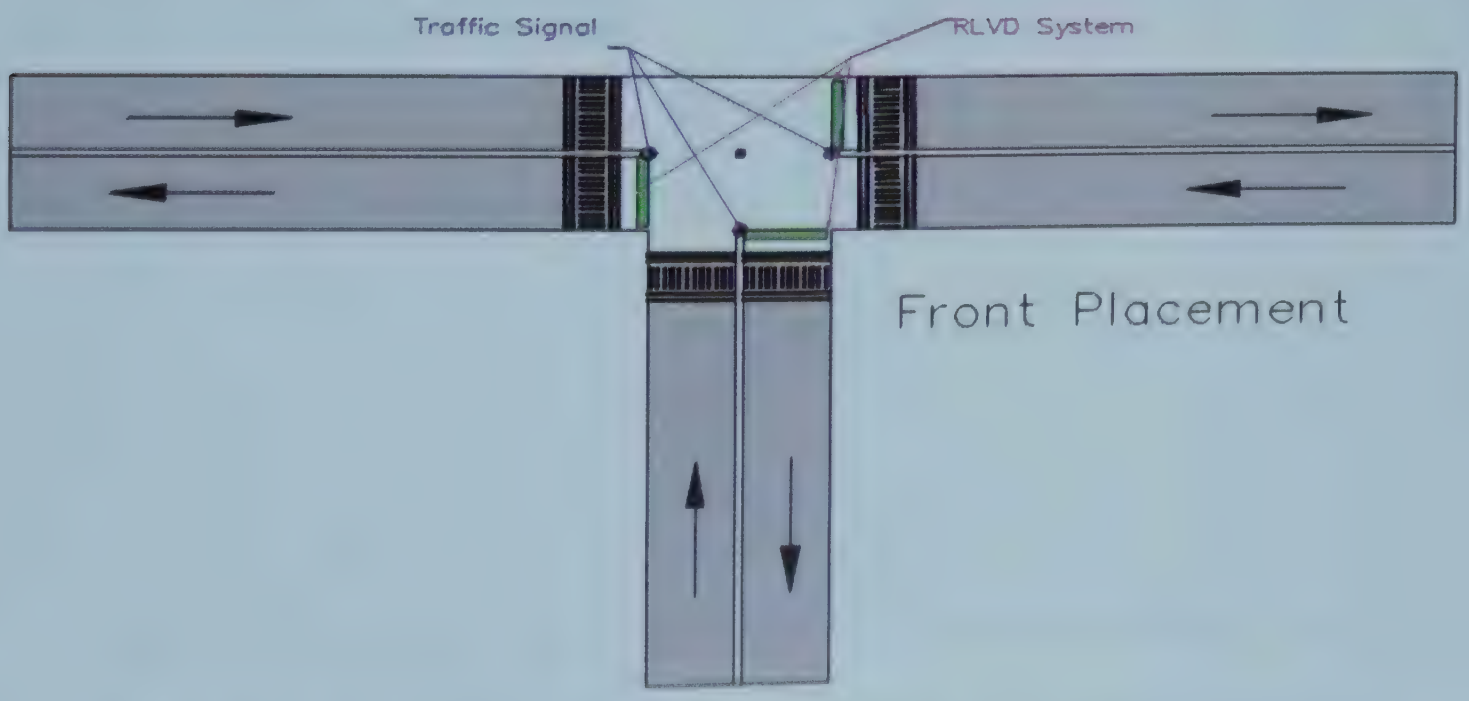

Fig. 12 The Front Placement of RLVD Devices in 3 - Legged Intersection

ii) **Rear Placement of Camera**

a) **4 - Legged Intersection**

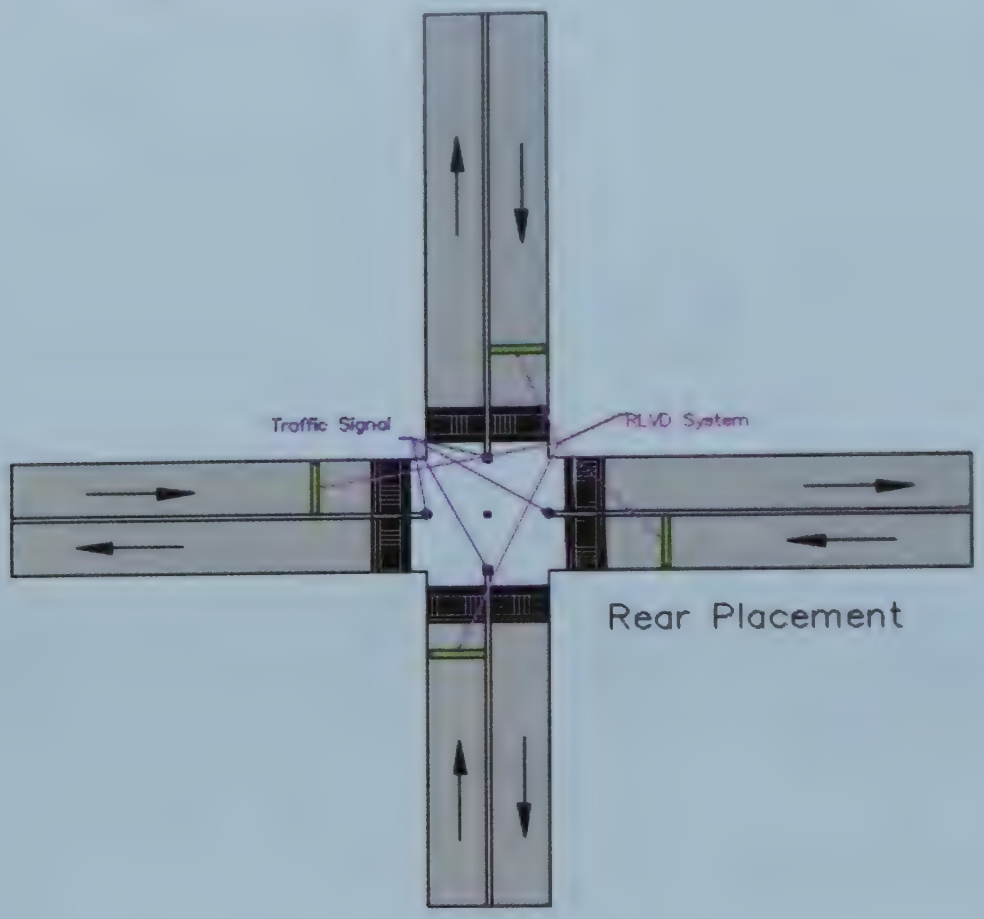

Fig. 13 The Rear Placement of RLVD Devices in 4 - Legged Intersection

b) **3 - Legged Intersection**

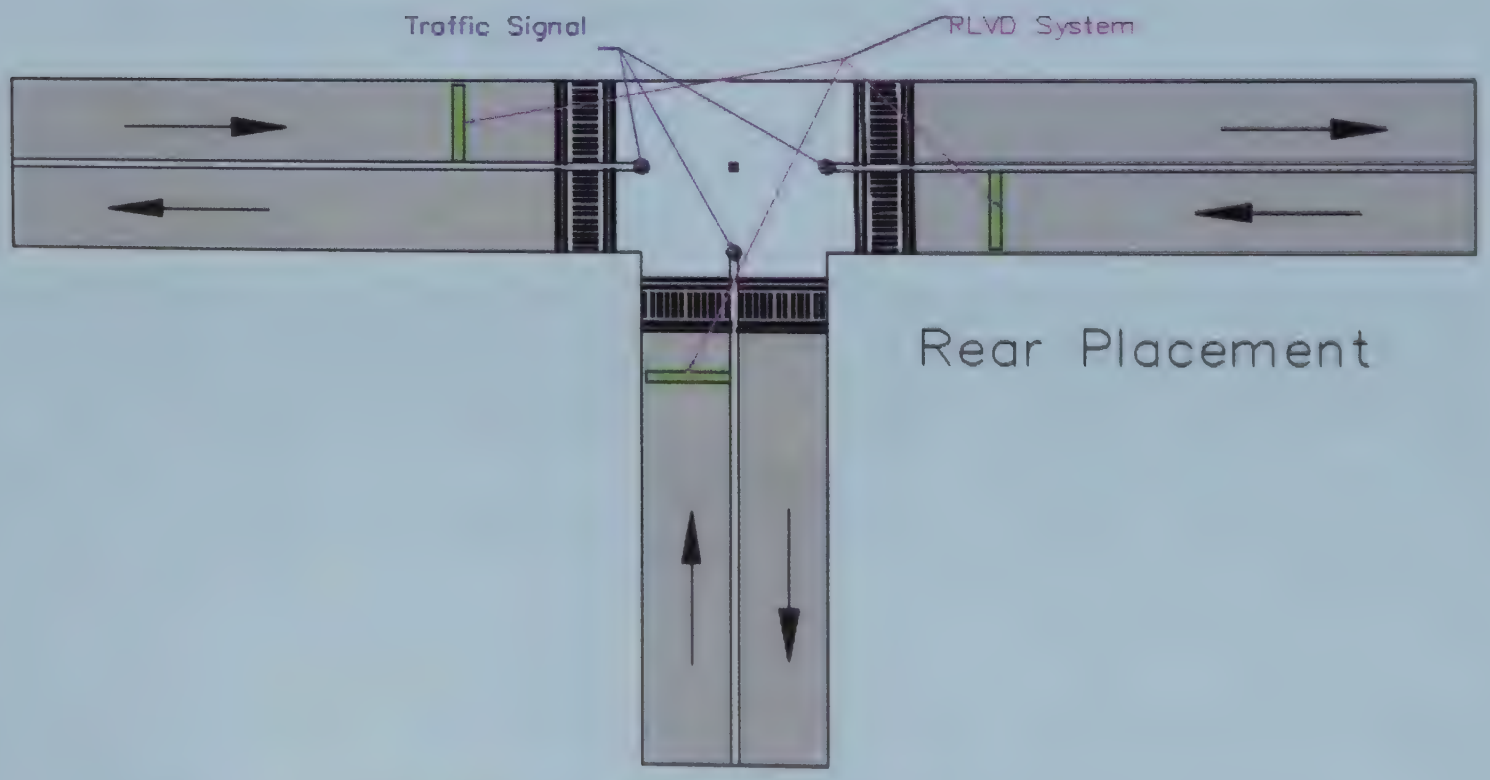

Fig. 14 The Rear Placement of RLVD Devices in 3 - Legged Intersection

4.5 Detailed Specifications for RLVD System

S.NO.	Category	Minimum Specification
1	Evidence Camera	• Evidence Camera (wide angle road view) should be Megapixel type IP cameras, 42592 X 1944 or better Megapixel per road true day & night camera • Lens size 2.7~13.5 mm/ 2.8~12 mm or similar • Colour images for day, monochrome images for night • CMOS Global shutter sensor with lens. • Video compression: H.264/H.265/JPEG • Video resolution: 2592 X 1944 or better • Lens Type Varifocal Motorized o Multiple streams: The camera shall be able to set up and stream out minimum three (3) stream profiles simultaneously. Each stream profile can have its own compression resolution, frame rate and quality independently. Primary stream at 5MP@25 fps, Other streams at 2 MP@ 25 fps • Frame rate: 25/30 FPS o Minimum illumination: Color mode: 0.05 lux @ F1.6 or better B/W: 0 lux with IR illumination on • Signal/Noise ratio: ≥ 50 Db • Supported protocols: standard protocols, ONVIF interface • Certification: EN/IEC/FCC /CE • Power supply: PoE (IEEE 802.3) or AC 24V/ DC12V, 100 - 230V AC
2	ANPR Camera for Number Plate Capture with IR Illuminator (1 lane per camera)	• ANPR Camera should be Megapixel type IP cameras, (min 2 MP camera per lane) True day & night camera colour images for day and night CMOS Global shutter sensor. • Lens size: 5~50 mm/ 8~40 mm, IR corrected. • Lens type: Varifocal, C/CS Mount / Built in Lens, IR Correction Full HD lens • Minimum illumination: Color mode: 0.05 lux @ F1.6 or better, B/W: 0 lux with IR illumination on • Supported Protocols : ONVIF, TCP/IP, Other standard Protocols • Minimum vertical resolution :1080 lines Exposure time maximum: 1 milli-second, with motorized / Non Motorized zoom lens. • Power supply: PoE (IEEE 802.3) or AC 24V / DC 12V, 100 - 230V AC

3	Infrared Flash for Illumination	• Infrared flash for image capture at night Synchronized flash with global shutter of camera Wavelength: 850 nm, Flash power sufficient to capture vehicle images also at night. Capability to capture retro reflective and non-reflective number plates. High cycle frequency with the capability to function in bursts of at least 4 consecutive flashes at intervals<200 msec
4	IR Illuminator for ANPR Camera	• Type: External IR illuminator with high performance LED (42 pcs high brightness IR LED), high efficiency, energy saving and environmental protection. • Wavelength: ≥850 nm (Infrared) • Illumination Range: minimum 50 m • Environment Protection: IP66 or better • IR Power: 80 W • Adjustable angle to appropriately focus at the number plate. • Beam Angle: Multiple options- 10 degree (standard), 15, 30, 45 degrees • Surge level: Common mode 6 KV, Differential mode: 3 KV • Certifications: CE, FCC, RoHS, IEC-62471 • Protection function: Transient over peak suppression • Housing material: Die-casting aluminium alloy • User Interface: RS485 • Eye safety certificate along with test report to be submitted for IR Illuminator. • The OEM should have manufacturing, sales and service centre in India
5	**ANPR Detailed Specification**	
	Vehicle Detection by Color and logo / Color and number plate	• The system shall detect the color of all vehicles in the camera view during daytime and label them as per the predefined list of configured system colors. The system shall store the color information of each vehicle along with the license plate information for each transaction in the database. • The system shall have options to search historical records for post event analysis by the vehicle color or the vehicle color with license plate and date time combinations. • The system shall detect make of vehicle by logo detection • The system shall classify the vehicles in minimum 4 (four) categories (2-wheeler, 3-Wheeler/Auto, LMV, HMV at any

	given point in time.) (these are non-working analytics and will not work in night, dawn and dusk).
Alert Generation	• The system should have option to input certain license plates according to the hot listed categories like "Wanted", "Suspicious", "Stolen", etc. by authorized personnel. • The system should be able to generate automatic alarms to alert the control room personnel for further action, in the event of detection of any vehicle falling in the hot listed categories.
Vehicle Status Alarm Module	• On successful recognition of the number plate, system should be able generate automatic alarm to alert the control room for vehicles which have been marked as "Wanted", "Suspicious", "Stolen", "Expired". (System should have provision/expansion option to add more categories for future need). • The Instantaneous and automatic generation of alarms. In case of identity of vehicle in any category which is defined by user the system should be able to work day & night. The system should be able to read and process number plates of vehicles on high speed more than 200 km/hr. External IR illuminator shall be used for accurate detection of number plates in night condition.
Vehicle Log Module	• The system shall enable easy and quick retrieval of snapshots, video and other data for post incident analysis and investigations. • The system should be able to generate suitable MIS reports that will provide meaningful data to concerned authorities and facilitate optimum utilization of resources. These reports shall include. • Report of vehicle flow at each of the installed locations for Last Day, Last Week and Last Month. • Report of vehicles in the detected categories at each of the installed locations for Last Day, Last Week and Last Month. • Report of vehicle status change in different vehicle categories. • The system shall have search option to tune the reports based on license plate number, date and time, site location as per the need of the authorities. • The system shall have option to save custom reports for subsequent use. • The system shall have option to export report being viewed to common format for use outside of the ANPRS or exporting into other systems.

		• The system should provide advanced and smart searching facility of License plates from the database. There should bean option of searching number plates almost matching with the specific number entered (upto 1 and 2 character distance)
	Vehicle Category Editor	• The system should have option to input certain license plates according to category like "Wanted", "Suspicious", "Stolen", "Expired" etc. by authorized personnel. • The system should have an option to add new category by authorized personnel. • The system should have option to update vehicle status in specific category by authorized personnel e.g. on retrieval of stolen vehicle, system entry should be changed from "Stolen" to "Retrieved". • System should have option to specify maximum time to retain vehicle records in specific categories.
	General Specification	• The system should be capable of generating video and minimum 5 or more snapshots in any of the standard industry formats (.MJPEG, .JPG, .AVI, .mp4, .mov etc.) with at least 10 frames per second.
		• The system should be able to perform ANPR on all the vehicles passing the site and send alert on detection of any hot listed vehicle. • The system should have ANPR / OCR to address the alphanumeric character of irregular font sizes.
	Central Management Module	• The Central Management Module shall run on the ANPR Central Server in control booth. It should be possible to view records and edit hot-lists from the Central Server
	Traffic Analytics	• The system shall detect the colour (RGB combination) of all vehicles in the camera view during daytime and label them as per the predefined list of configured system colours. The system shall store the colour information of each vehicle along with the license plate information for each transaction in the database. • The system shall have options to search historical records for post event analysis by the vehicle color or the vehicle colour with license plate and date time combinations and vehicle make. • The system shall classify the vehicles in minimum 4 (four) categories (2-wheeler & 3-Wheeler/Auto, LMV, HMV at any given point in time.)

		• ANPR shall be capable to detect Vehicle counts, Average speed, Wrong way detection and Stopped vehicle. • No helmet and triple riding detection shall have 90% or above accuracy. • The ANPR system shall have capability to detect delay in travelling time of a particular vehicle from one point the other.
	Average Speed	Average speed computation between two locations using ANPR cameras.
6	**RLVD Specification**	
		• The system should be able to process and read number plates of vehicles with speed even more than 200 km/hr. • The system should be able to capture the speed of the vehicle at the time of red light/stop light violation. • The proposed OEM should have been experienced in proven red speed. • The over view camera should provide at least 5 frames (or user configurable) of the offending vehicle as evidence. • The system should have the facility to provide the live feed of the camera to the central monitoring station or as per employer's requirement. • The system should not use any sensor to detect the presence of the vehicle in the field of view i.e., the system should be totally video based system. • The system should be able to provide video clips of the transaction also from the overview and lane cameras also as evidence. • The system should do processing locally on the LPU installed at the junction. • The system would be able to take input of the traffic light controller/signal for detecting the phase of the traffic light. • System should be able to detect both Stop line violation and Red light violation and categorize them separately as violations • For each detected violation, the system would store 5 snapshots of both cameras, date and time, location, ANPR recognized license plate number, thumbnail of the license plate region, phase of light (red, amber), time since phase change (red, amber) and speed of the violating vehicle at the LPU.

- System would have option to record video of over view camera either during red phase of the traffic light only or always as per user requirement.
- All evidence pictures should be saved in encrypted mode only so that it should be able to prove that the picture has not been tempered with.
- The evidence image produced by the system should be wide enough to give the position of the infracting vehicles with respect to the stop line and indicate color of the Traffic light. The vehicle number plate should be readable in the evidence image.
- System should have capability to track vehicle on map.
- System should have facility to define routes for commercial vehicle.
- System should have capability to generate alerts / alarm if any vehicle changes its designated route.
- The system design should be based on open architecture and should have unrestricted scope for scalability and integration with similar surveillance systems in use or likely to be used by the employer. The system usage shall have role-based access with following features protected with individual passwords. All logins should be logged. These logs should be non-tamper able.
- Administrator – Full access to all functionalists
- Operator – Access to all functionalists (including recorded events) except system configuration
- Viewer – Access only to reports / Live screen
- Apart from Red-Light violation detection, the system should perform ANPR on all the vehicles passing the site and send alert to the central server on detection of any Hot-listed vehicles (whose numbers have been marked as Stolen, Wanted, etc. at the Central server).
- The system should have reading accuracy of 90% on vehicles including 2 & 4 wheelers which are visible by human eye for English alphanumeric number plates excluding cursive fonts.
- The system should have an option for the user to enter Hot-listed vehicles at the Central Server and the same should be sent to all the sites automatically over the network.
- The LPU at local sites should send transaction data for all violations and alerts of Hot-listed vehicles to the central server. Alerts should be sent immediately, whereas violation

		data should be sent in batch mode as per available bandwidth. • The system should be able to do No helmet and Triple ridding detection for 2-wheelers. • Encrypted data and images pertaining to Violations should be transmitted to the Back office electronically through GPRS/3G/leased lines or any other better means of network. • System should locally store violation data at the LPU, for 30 days to take care of non-availability of connectivity. • The proposed system should have the capability to transfer the data to Central Command Center through proper encryption in real time. Proposed application for traffic violation detection system should adhere to National Cyber Security Policy to ensure that the critical information processed and stored by the proposed application is secure from cyber-attacks. • System should be able to detect Wrong Direction Vehicle Movement in the ANPR camera view and also read the number plate using ANPR technology. **Challan Generation** a) The system should have facility to generate the challan using Challan generation software. b) The system shall be able to export all violation data captured including snapshots to the Challan Generation software being used by the state police / transport department, for further processing.
7	Local Processing unit (LPU)	LPU with pre-loaded with RLVD and other features module like ANPR system, SVD/Wrong-Way detection, Free-left detection and No-Helmet detection software will be used to process the video feed from the camera and capture the Vehicle Number plates with other features like Speed of the vehicle, Date/time of crossing the camera field of view, location where vehicle is captured etc. It will push the captured data to Central Monitoring System (CMS). It will be placed inside the Junction Box along with other items like Network switch etc. AC/DC converter (similar to Laptop adapter) will used to power the LPU.
		Local Processing Unit shall be of Aluminium Alloy Casing
		Local Processing Unit shall be of min. 7th Generation with core i7 CPU
		It should have 2 nos. LAN, 16 bit DIO, SATA, 4 COM, 6-48V DC Wide Voltage Input
		It shall support GPU HD Graphics 630 min.
		Memory- DDR4 2133MHz SODIMM, up to 32 GB

		Display Port- 1 nos. VGA, 1 nos. HDMI, 1 nos. DP It shall support Secondary Storage 2×2.5" SATA HDD/SSD Bay It shall support USB- 6 nos. USB 3.0 and 2 nos. USB 2.0 It shall have LAN- 6 nos. Intel I210AT PCIe Gig. Ethernet; 1 nos. Intel I219LM PCIe Gig. Ethernet support iVpro Power- Voltage Input: DC6~48V AC Input: External Adapter (Option) Voltage Input: 100VAC~240VAC@50~60Hz Temperature- -40°C ~ 85°C Certifications- CE, FCC, BIS &MIL-STD-810G certified for Shock & Vibration resistance. It shall withstand vibrations as per 5 grms / 5 ~ 500Hz /in work status (SSD) 1 grms / 5 ~ 500Hz / in work status (HDD) It shall withstand shock as per 50 g peak acceleration (duration 11ms) (SSD) 20 g peak acceleration (duration 11ms) (HDD) ANPR platform, LPU should be proposed by same OEM to have to esnure seamless integration & for accurate performance and manageability. The OEM should have manufacturing, sales and service centre in India
8	Infrared Flash for Illumination	• Infrared flash for image capture at night Synchronised flash with global shutter of camera Wavelength: 850 nm, Flash power sufficient to capture vehicle images also at night. Capability to capture retro reflective and non-reflective number plates. High cycle frequency with the capability to function in bursts of at least 4 consecutive flashes at intervals<200 msec • Flexible angle adjustments: 30^0, 45^0, 60^0, 90^0
9	Violation Images	• For each red-light violation one lane – ANPR image of vehicle with clear number plate images and 2 evidence images and a five second video clip of the violation should be captured. (Video on demand from site)
10	Vehicle Image Capture	• Along with number plate, high quality image of vehicle, also to be captured at Day and Night conditions for all vehicles. Evidence camera should capture wide angle shot of full road and surroundings with minimum five images of vehicle moving on the road.
11	All Vehicle - ANPR Capture Mode	• Captures all vehicles passing through the installed location. All vehicle images and numbers are kept in database for real time alerts / search for crime analysis. Vehicle images should be captured even if the number plate is not automatically detected, (example: damaged /

		unreadable number plates or even absence of number plates)
12	ANPR Accuracy	• High ANPR accuracy > 90% all around capability for standard or near standard number plates with maximum 1 character error.
13	Vehicle Detection Rate (percentage of vehicles captured)	• High vehicle detection rate: greater than 90% of all vehicles captured under all conditions, irrespective of number plate quality, in free flow traffic conditions.
14	Rear Side Capture	• Should support rear-side capture
15	Classification	• Should be possible to classify 2-wheeler, Auto etc. 3-wheeler/Auto, LMV, HMV etc.
16	Lightning Arrester	• As per BIS standard IS 2309 of 1989
17	Roadside Processing Hardware and Software, Storage, Network Switch	• Roadside Embedded hardware, network switch etc. Local storage with 256GB or more storage at site. All industrial grade hardware should be provided. • Security: Password protection, user authentication, HTTPS encryption etc.
18	RLVD Configuration	• All approaches to the junction, 1-3 lanes per approach
19	Power supply	• Main power with 2-hour backup with lightning, under/over voltage protection etc.
20	Health Monitoring and Control. (From Control Room)	• Temperature, battery status, Power supply working status, Camera status. Remote control of system. The Health Monitoring Data should be transmitted to the centralised backend system. Health monitoring information and alerts should be displayed in the control room.
21	Field Enclosure	• Pole mounted outdoor type, with rugged, with Rain canopy etc. All connectors, cables etc. should be of industrial grade and any hardware should be easily replaceable • Casing: IP 65 rating or above, IP 67 rating
22	Operating Environment for all Field Equipment	• 0-55 ^{O}C, up to 95% Relative Humidity.

23	Data Encryption between Field Equipment and Control Centre	• Advanced Encryption Standard (AES)

4.6 E-Challan System

Integrated e-Challan Software is an electronic system to issue challans from the central location, to the vehicles violating traffic rules. All Traffic enforcement solutions will be integrated with e-Challan software. It can be integrated with databases like RTO/VAHAN/Sarathi etc. to collect the name, address and other details of the vehicle owner. Challan can be generated automatically from the central location. Challans to be approved by authorized personal before final printing. It can be integrated with and held terminal for spot challan generation **(Fig. 15)**.

4.7 Detailed Specifications of E-Challan

1	E-Challan software shall work in client-server mode, where the devices units, workstation units will act as clients connected to the server through cellular network for data transfer.
2	E-Challan system shall be able to retrieve vehicle owner's details and vehicle data from Vahan/eSarthi data base to minimize data entry.
3	E-Challan system shall be able to retrieve vehicle system registration details and driving license details by reading appropriate smart card to minimize data entry.
4	Server should maintain log of all current devices. Any access to the system must be recorded along with data, time user id and IP address.
5	A unique Challan number should be generated through client software for each challan.
6	As soon as a vehicle registration number capture through ANPR Camera , System automatically check from the server if the vehicle is stolen, wanted in any criminal case or is in the list of suspicious vehicles.
7	The most frequent traffic offences should be kept at the top of the drop-down menu and offence ingredients should be available, if required by officer.
8	Date, time and GPS coordinates of place of challan should be automatically populated in the relevant fields of client software.
9	Compounding amount must populate in the field automatically from master table.
10	The successful bidder should develop the GUI and functionality as per requirements.
11	It should be possible to integrate payment gate way operator with the system for facilitation of payment.
12	The Application Software should work in a web-based environment.
13	The Application Software should be user friendly, easy to operate.

14	The application software should maintain the logs of user activities to facilitate the audit trail.
15	Database server should be able to handle the activities of all the handheld devices at one time simultaneously with huge database size of prosecution, ownerships, driving license etc. without affecting the performance.
16	The software should be able to generate various periodical reports, summaries, MIS reports, query reply etc. as per the requirements.
17	Administrator should be able to modify the master tables as and when required and should have the capability to push the changes to hand-held devices.
18	All database tables, records etc. required for various drop down menus etc. shall also be created by the vendor.
19	E-Challan system should show alert on handheld device in case speed system detect any violation.
20	In case of speed violation, E-Challan system will send alert and SMS to nearby officer using geofence.

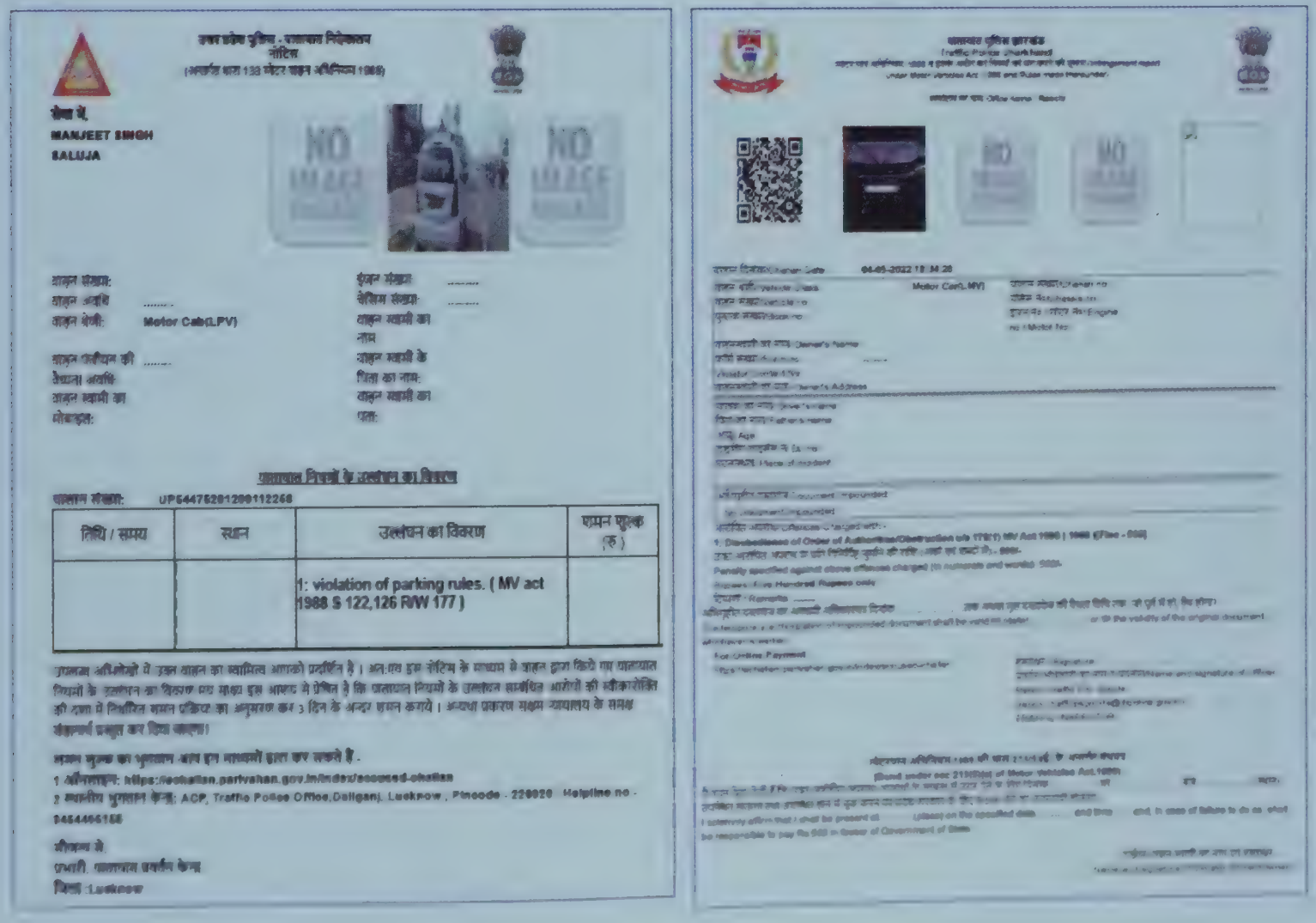
उत्तर प्रदेश पुलिस - परिवहन निदेशालय
नोटिस
(मोटर यान अधिनियम 1988)
सेवा में,
MANJEET SINGH
SALUJA
NO IMAGE
NO IMAGE
वाहन संख्या:
वाहन श्रेणी: Motor Cab(LPV)
इंजन संख्या: .....
चेसिस संख्या: .....
वाहन स्वामी का नाम
वाहन स्वामी के पिता का नाम:
वाहन स्वामी का पता:
उल्लंघन विवरण की उल्लंघन का विवरण
वाहन संख्या: UP54AT6281200112268
तिथि / समय
स्थान
उल्लंघन का विवरण
शमन शुल्क (रु.)
1: violation of parking rules. (MV act 1988 S 122,126 R/W 177)
शमन शुल्क का भुगतान आप इन माध्यमों द्वारा कर सकते हैं -
1 ऑनलाइन: https://echallan.parivahan.gov.in/index/accused-challan
2 स्थानीय भुगतान केन्द्र: ACP, Traffic Police Office,Daliganj, Lucknow , Pincode - 226020 Helpline no - 9454496158
प्रभारी, यातायात प्रवर्तन केन्द्र
जिला :Lucknow
Motor Cab(LPV)
04-05-2022 18:34:26
Motor Cab(LPV)
1: Disobedience of Order of Authorities/Obstruction u/s 179(1) MV Act 1988 | 1988 (Fine - 500)
Penalty specified against above offences charged (in numerals and words) 500/-
Five Hundred Rupees only
For Online Payment

Fig. 15 Sample Illustration of Challan Forms

5 OPERATION AND MAINTENANCE OF RLVD SYSTEMS

5.1 Introduction

The operation and maintenance of a Red-Light Violation Detection System involves the management and upkeep of the technology used to monitor and enforce traffic signal compliance at intersections. Here are some key aspects of operating and maintaining such a system:

- **System Installation:** The Red-Light Violation Detection System is installed at selected intersections or locations where traffic violations are likely to occur. The system includes cameras, sensors and associated hardware and software components.
- **System Calibration:** After installation, the system needs to be calibrated to ensure accurate detection of red light violations. This involves adjusting camera angles, sensor sensitivity, and other parameters to optimize performance.
- **Monitoring and Detection:** Once the system is calibrated, it continuously monitors the intersection for red light violations. The cameras capture video footage and images, and the software analyzes the data to identify potential violations.
- **Violation Verification:** When a potential violation is detected, it undergoes a verification process. Trained personnel review the captured footage to confirm whether a violation has indeed occurred. They assess factors such as the position of the vehicle, the state of the traffic light, and the timing of the violation.
- **Issuing Citations:** If a violation is verified, a citation or ticket is issued to the registered owner of the vehicle. The citation typically includes details such as the date, time, location, and evidence of the violation. The citation is then sent to the vehicle owner through the mail or electronically.
- **Maintenance and Upkeep:** Regular maintenance is essential to ensure the proper functioning of the Red-Light Violation Detection System. This includes inspecting and cleaning cameras and sensors, replacing any faulty components, and updating software as needed. Maintenance schedules may vary depending on the specific system requirements.
- **Data Management and Reporting:** The system generates and stores data related to red light violations, including images, videos, and violation records. This information is typically managed and stored in a centralized database. Authorities can use this data for monitoring traffic patterns, identifying hotspots and generating reports on violations and enforcement activities.

- **System Upgrades and Enhancements:** Over time, system upgrades and enhancements may be necessary to improve performance or incorporate new features. This could involve software updates, hardware replacements or adopting advanced technologies.
- **Training and Staffing:** Adequate training should be provided to personnel responsible for operating and maintaining the system. This includes training on system operation, violation verification procedures, maintenance tasks, and data management protocols. Sufficient staffing levels should be maintained to ensure timely response to system issues and violations.
- **Compliance and Legal Considerations:** Red-Light Violation Detection Systems must comply with applicable laws, regulations, and privacy considerations. It is important to ensure that the system is implemented and operated in accordance with legal requirements and that the privacy of individuals is protected.

By following these steps and maintaining the system properly, the Red-Light Violation Detection System can effectively contribute to improving traffic safety and enforcing traffic regulations at intersections.

5.2 Enforcement using RLVD

The driver approaching the red light always faces a dilemma to cross the signal or to slow down in case the signal turns amber and eventually red. This concern was largely addressed by the timers present on the signal, which give a clear indication on time to red/ amber. The free passage that the vehicle of a particular stream has is indicated by the countdown timer.

Once the driver sees the approaching signal turning amber, the driver faces a dilemma about whether to accelerate and unsafely cross the system or to decelerate and stop at the junction. Some drivers (mainly aggressive and novice drivers), who perceive that they can cross the signal within the amber time, but are not able to cross the intersection, get stranded either in the middle of the intersection, or on the pedestrian crossing, causing inconvenience to the pedestrians as well. The idea behind the above system is to issue fines/ notices so that this unsafe practice could be reduced and the discomfort to pedestrians (specially differently abled pedestrians) could be lowered to a great extent.

To cater this, the red-light violation device must be triggered and then accordingly the fines must be issued. There is an amber light and a countdown timer present at the junction to make the driver aware to decelerate the vehicle and stop before the stop line/ wait for the next green time to cross the intersection. If the driver is still not stopping before the stop line despite these

two visual warnings, the driver is liable to be fined. **Table 4** shows when should the red-light violation device be triggered and should furnish notices to such violators.

Table 4 Working of RLVD System

Sl. No.	Signal Phase	RLVD System State	Action being taken by RLVD	Remarks
1	Red Phase	Triggered after 0.2 sec of start of Red Phase	Fines Issued, Images and video evidence captured	The vehicles crossing a particular line (Stop line) with a speed greater than a threshold speed would be captured and fines would be issued
2	Amber phase	OFF State	No Action	If it is integrated with TMS / ATMS, then the speed of vehicle crossing the junction can be monitored and accordingly enforced, keeping safety in view.
3	Green Phase	OFF State	No Action.	

Based on the following factors, RLVD systems can accurately identify red light violations and distinguish them from mere stop line violations.

High-Resolution Cameras: RLVD cameras capture images and video footage of the intersection. They can identify, if a vehicle crosses the stop line after the signal turns red, providing visual evidence.

Time Stamps: RLVD systems record the precise timing of the traffic signal changes and the vehicle's movement. This information is crucial for determining, if a violation occurred during the red signal phase.

Algorithmic Analysis: Dedicated software processes the data from sensors and cameras, evaluating vehicle movements and signal timings. It can differentiate between vehicles stopping correctly and those that violate the red light.

Image Recognition: Image recognition software can also read license plates and provide additional information about the vehicle, aiding in fine differentiation.

5.3 Limitations of RLVD

Presence of RLVD not only imparts safety in the system, but also creates a sense of fear in the driver's mind about being fined. The Drivers to save themselves from the fine, either accelerate and unsafely cross the junction in amber time (when the camera is off) without stopping, or they tend to stop the vehicle with haste and apply hard brakes to decelerate more and stop before the stop line. This behaviour results in the rear collision, the driver of the succeeding vehicle is unable to perceive that the driver of preceding vehicle would decelerate faster than

usual, causes discomfort, and rear end collision in some cases. A study in Sydney reported 35% increase in rear end collision when the system was implemented.

5.4 Maintenance of RLVD Systems

The Red-light violation problem at any intersection needs to be investigated and the feasibility of all countermeasures, including red light camera systems, should be addressed. A systematic approach to the collection and analysis of various intersection safety-related data is important for the identification of intersections where there is a high incidence of Red-light violation and for the investigation of countermeasures.

5.5 Data Collection

An identification of intersections with high crash rates, public complaints, and those identified by law enforcement as having violation problems, is the first step in improving intersection safety. While complaints or other inputs from motorists and the public about Red-light violation at specific locations are helpful, data on crashes resulting from Red-light violation and the number of Red-light violations at signalized intersections are required for an objective assessment of the potential safety problems and an understanding of factors that may be contributing to the problems. Data for investigating intersection safety may be obtained from the following sources:

- Crash statistics and investigation records maintained by law enforcement and traffic engineering agencies.
- Crash statistics maintained by insurance companies, if available.
- Counts of citations issued by law enforcement officers for Red-light violation.
- Camera surveys of driver behaviour at intersections, including counts of Red-light violations.
- Field observations of driver behaviour at intersections, including speed surveys, by trained personnel.
- Complaints or other inputs from motorists and the public.

5.6 Intersection Crash Data

State and local agencies typically collect crash data for injury crashes or crashes where property damage exceeds a pre-determined threshold amount. Generally, data regarding minor non-injury crashes are not collected. Crash data is the most comprehensive basis for the

identification and analysis of Red-light violation at signalized intersections. The data should be classified with as much detail as possible, including:

- Intersection location, by identifier or street names.
- Crash type, for example, angle collision, rear-end collision, or striking a pedestrian or bicyclist.
- Crash location and vehicle movement, including movement direction, left turn, though, or U-turn.
- Crash day of week and time of day.
- Weather at the time of the crash.
- Type of vehicle: automobile, SUV, truck, bus or motorcycle.
- Vehicle speeds.

5.7 Red Light Violation Data

An analysis of Red-light violation data may serve as an alternative to the crash data when crash data are not available. This data may be available from records maintained by law enforcement or from special studies collected by video cameras or other means. However, this approach is generally not recommended because the data may reflect targeted enforcement at selected intersections only and the criteria applied by individual officers for issuing citations may vary from one officer to another.

5.8 Driver Behaviour Observations

Video surveys or field observations may also provide important data on driver behaviour and operational conditions at intersections. Conditions such as traffic repeatedly backing up into an intersection from adjacent freeway ramps or intersections, traffic backing into the through lane from the left-turn bay or high speeds on the intersection approaches may be contributing to red light violations and to the incidence of crashes attributable to Red-light violation.

5.9 Traffic, Signal, and Intersection-Related Data

Intersection geometry, traffic volumes, and signal timing data are generally available from the State or local agency traffic engineering or public works department. The following data provide necessary information for a rigorous analysis of factors that may be affecting the frequency of crashes attributable to Red-light violation:

- Signal operation: coordinated, fully actuated, semi-actuated, pre-timed, or isolated.

- Signal phasing: protected, permissive, or protected-permissive left turns, split phasing.
- Yellow interval.
- All-Red interval.
- Number of traffic lanes.
- Number and location of signal heads.
- Vehicle detector locations.
- Approach angles, speed limits, and directions.
- Street lighting.
- Approach grades and visual obstructions.
- Average daily and peak period traffic volumes.
- Proportion of tall or wide vehicles.

A sample assessment form that can be used as a guide for field inspections of problem sites can be found in Intersection Safety Issue Briefs.

5.10 Motorist Complaints and Comments

Qualitative means to identify intersections where Red-light violation is a frequent occurrence should also be employed by State and local agencies. Through the solicitation of inputs from motorists and from the public, intersections where there are unique or changed conditions or where motorists have witnessed "near misses" that might not otherwise be identified from an analysis of crash data can be considered for further analysis and investigations. Written and oral complaints from motorists may be used as an input for determining intersections where there is a problem with Red-light violation.

5.11 Engineering Study

The State or local agency considering the use of a red-light camera system should conduct an engineering study to determine the factors contributing to Red-light violation and to identify appropriate countermeasures that could be implemented to reduce the number of crashes resulting from Red-light violations. Once identified, the appropriate effective countermeasures (engineering, education, and enforcement) should be considered in addressing the crash problem.

5.12 Other O&M Requirements

The following requirements need to be understood clearly so that handle the RLVD System effectively during design and O&M Period:

Environmental

- The system shall work without any degradation in all ambient environmental (temperature, humidity, precipitation) and seismic conditions.
- If any equipment does not comply with the ambient conditions, the surrounding atmosphere shall be modified to match the equipment's environment range. This shall be particularly applicable for equipment installed indoor with air-conditioning.

Operations Manual

The Operations / User manual shall be developed to facilitate ease of operations. It shall describe at least the following:
The organisation structure – Organogram, Designations, List of Personnel, Escalation Matrix. Escalation Matrix shall have a list (name, contact details) of personnel to escalate an unresolved issue.

Operations Methodology

- Working Methodology - step by step working of system, functioning of each menu option, screenshots and workflows so that the each of the system users may easily operate it.
- Role and Responsibility of each Personnel,
- Access Level,
- Control and Monitoring Methods,
- Safety and Security of Personnel, Data and Assets.

Following all the installation guidelines:

- Installation of Camera, IR's, I/O modules and LPU in the field.
- Pole designing and Pole installation along with proper stability.
    - Earthing, regulated & un-interrupted power supply to all installed equipments.
    - Proper enclosure along with ventilation to be provided for all field equipments.
    - Enclosure along with ventilation to be checked.
    - Safety harness with proper carabiner.
- All safety measures should be taken for field activities.
- Network Bandwidth as per requirement.
- Data storage duration to be provided on or before server installation.

An annexure providing contact numbers and emails of personnel in escalation matrix. This shall be updated whenever there is any change in details or when operations Manual is revised, whichever is earlier. Annexure containing the formats used for operations.

The Operations Manual shall be revised annually after receiving feedback from the stakeholders.

Maintenance Manual

It shall contain the following sections:
Organogram / organisation chart list of authorised personnel access levels escalation matrix.

Preventive Maintenance – This includes the periodic maintenance of the system even if there is no system breakdown or error reported. It shall contain the following:

- Annual Preventive Maintenance Schedule for approval by competent authority.
- Maintenance check-sheet showing equipment location, name, serial number, test / maintenance to be performed, tools to be used, safety measures to be followed, approximate time duration for each activity status of each test / maintenance activity.
- A summary report at end of each scheduled maintenance activity showing corrective action to be taken, if any.

Breakdown Maintenance – Breakdown maintenance shall be undertaken when is a deviation from intended performance or form. This shall include:

- Methodology for fault reporting.
- Spare parts / defective parts tracking system.
- The maintenance activity details as well as parts management shall be inputted in the Maintenance Module.
- The system shall automatically calculate the downtime and applicable penalties, if required uptime is not achieved. This shall be made available in a report.
- The system shall also have a provision to calculate applicable penalties in case the performance standards are not met.

Training

It is important to ensure that the Operations team as well as Authority's staff should be imparted periodic in-depth training of the system. The trainer shall provide sufficient operation and maintenance training such that the key personnel become fully conversant with the contents of the equipment and equipment working. Training program shall be prepared and presented to the Authority for approval. Training shall be imparted prior to system commissioning as well during the O&M period, During the O&M period the training shall be provided to new personnel and a refresher course to all related personnel at least once per year.

The training shall be in-depth series of sessions which shall comprise of both classroom type training as well as practical training. The training shall be specific to both classes of personnel, these being Operational and Maintenance personnel. The agency shall supply all training materials and conduct the training to satisfy the users. This shall conduct post-training test along with the issuance of Training Certificates.

The training programme shall comprise of the following minimum requirements:

- A start up program detailing the purpose, usage and functionality of the integrated system (Practical and Theory Training).
- A program detailing the functions and specific features of each sub-system and its associated equipment components (Practical and Theory Training).
- A program detailing the operation, administration and maintenance of the equipment components, sub-systems and integrated system (Practical and Theory Training).
- The equipment manuals shall be referenced and utilised during the training sessions.

6 CASE STUDIES FOR RED LIGHT VIOLATION DETECTION

6.1 RLVD Systems in India

Delhi

In February 2019, the Delhi Traffic Police, in collaboration with Maruti Suzuki India Limited, introduced the Red Light Violation System (RLVS) shown in **Fig. 16**. This advanced system incorporates state-of-the-art technology to enhance traffic monitoring and enforce compliance with traffic rules. Equipped with sophisticated 3-D radars and over 100 high-resolution cameras, the RLVDS enables comprehensive tracking of vehicles and the detection of various traffic violations.

The system's cameras have the capability to capture multiple offenses, including red light violations, speed violations, stop line violations and wrong-side violations. By utilizing these cameras, the RLVDS can effectively identify violating vehicles and record their registration numbers. Furthermore, the system automatically encrypts and transfers the violation data to a centralized server located at the Delhi Police control room.

One of the key features of the RLVDS is its ability to generate e-challans, which are electronic traffic violation tickets, accompanied by photo evidence. Once a violation is detected and recorded, the system facilitates the issuance of e-challans, which are then sent to the violators via SMS, email or post. This streamlined process ensures that violators receive timely notifications and evidence of their infractions.

The introduction of the RLVDS in Delhi represents a significant step towards enhancing traffic enforcement and improving road safety. By leveraging advanced technology and efficient data management, this system enables the Delhi Traffic Police to effectively monitor and deter various traffic violations. Through the issuance of e-Challans and the provision of photo evidence, the RLVDS promotes accountability among motorists and encourages compliance with traffic regulations.

Fig. 16 RLVDS Implemented by Delhi Police

Lucknow

Largely Implemented in 2020, RLVD in Lucknow now has more than 800 cameras at 130 major spots in the city. These devices are capable of issuing notices for the following offences: triple driving, driving without helmet, wrong side, red light violations, stop line violations Lucknow has also integrated the system with the traffic police personnel, which include on spot challans, for the offenses that were not captured in the camera. The distinguishing factor in Lucknow is that the signals at these intersections are also AI enabled that change their cycle times to avoid long queues at the junctions.

Bhubaneswar

Bhubneswar smart city is the Prestigious Project of India implemented in 2018 with ANPR with Traffic - Red Light Violation Detection System RLVD, Stop line, Speed, Wrong way, Free Left, Central Monitoring Software and Integrated E-challan System Central Software Module. All the Traffic solutions are based on advance AI technology and adding values in terms of reducing accidents, avoiding Traffic collisions, Capturing violations and making fines. All the solutions are successfully running in people safety and also helping Police for the necessary actions at the right time.

Hyderabad City

Its City Project of Hyderabad where Traffic solutions installed are ANPR with Red light violation detection system, Speed violation detection, wrong way driving detection system, Free left obstruction detection system, E - challan system, No helmet detection installed in multiple lanes and observed with accuracy of 90% most of the time. All the Traffic solutions are powered by AI and using latest technology algorithms to enhance the best accuracy and results. It is also helping Police department to automate things and reducing manual intervention because of AI driven alerts for the violations and pinpoint the incidents for easy investigations.

Bhopal

The smart city mission included Bhopal since it offered the city a new face in terms of education, research, tourism, well-connected and sustainably constructed societies. Bhopal, being a mid-sized city, suffered intense and chaotic traffic flows, which resulted in traffic congestion, serious accidents, and fatalities because of continuous violations of traffic laws, particularly at intersections. This increases travel time, which has a negative influence on social and economic activity. Transportation and traffic safety experts proposed video and image surveillance systems to stimulate law enforcement and create a safe and secure city for inhabitants as a solution to this problem. This medium-sized city features a Red-Light Violation Detection (RLVD), Speed Violation Detection, Automatic Number Plate Recognition (ANPR), No Helmet Detection, and Triple Riding Detection Intelligent Traffic Management System (ITMS) unit with 23 junctions. ANPR has been equipped with IP cameras, mostly at intersections, to improve law enforcement by detecting duplicate licence plates, banned drivers,

and red-light violators. The advantages of ITMS do not stop there; it also enables for traffic behaviour monitoring and management of traffic violation records. To create e-challans against violators, the Integrated e-Challans Management Software (ICMS) has been implemented. Citizens become more aware of traffic laws and begin to follow them as challans are delivered to the registration car address. As a result, the number of traffic signal violators decreases, as does the number of e-Challans. ANPR has been equipped with IP cameras, mostly at intersections, to improve law enforcement by detecting duplicate licence plates, banned drivers, and red-light violators. The advantages of ITMS do not stop there; it also enables for traffic behaviour monitoring and management of traffic violation records. To create e-challans against violators, the Integrated e-Challans Management Software (ICMS) has been implemented. Citizens become more aware of traffic laws and begin to follow them as challans are delivered to the registration car address. As a result, the number of traffic signal violators decreases, as does the number of e-Challans.

Prayagraj

The Integrated Command and Control Centre (ICCC) in Prayagraj is a modern technology infrastructure that enables the efficient collation, analysis, and visualization of information from various sources to aid decision making. Its intelligent operations capabilities help different stakeholders to prepare for emergencies, coordinate and manage response efforts, and enhance the ongoing efficiency of city operations. One of the significant benefits of the ICCC was witnessed during the 2019 Kumbh Mela, where it played a crucial role in ensuring the safety and proper management of the public gathering. The installation of ANPR (Automatic Number Plate Recognition) cameras at 19 major intersections locations was a key feature. These cameras had a minimum resolution of 2 MP and were equipped with infra-lights to detect traffic during night time. The cameras were installed 18 m before the stop line, and the cantilever height for installation was 6 m.

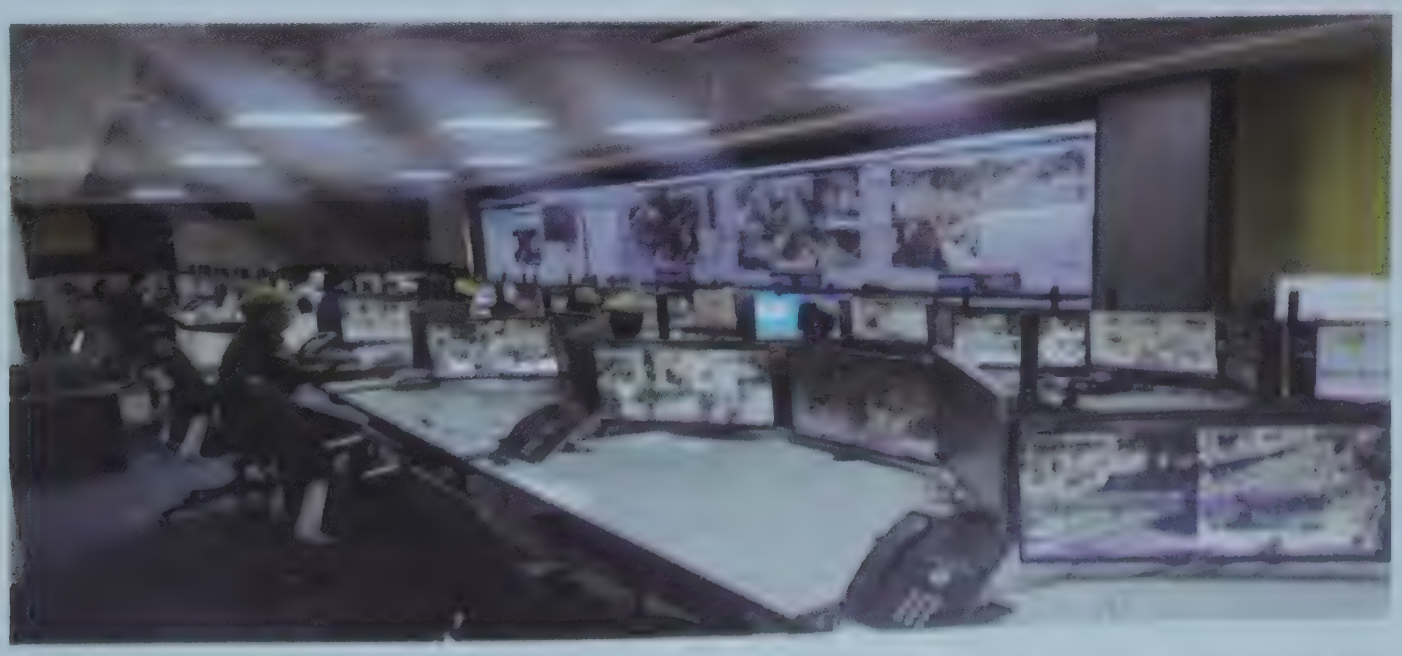

Fig. 17 Modern Traffic Control Centre using RLVDS at Prayagraj Smart City

The ANPR cameras helped in tracking the movement of vehicles and identifying suspicious activities, which helped in maintaining law and order during the event. The ICCC also enabled real-time collaboration among different agencies, including law enforcement, emergency services, and city officials, to respond promptly to any situation that arose during the Kumbh Mela. Overall, the ICCC in Prayagraj has proven to be an essential tool for the efficient management of city operations, particularly during large-scale events. Its capabilities in data collation, analysis, and visualization have the potential to enhance decision making across various sectors, including transportation, law enforcement, emergency services, and disaster management.

Bangalore

In Bangalore, traffic offences are being monitored by new advanced cameras equipped with Artificial Intelligence (AI), an SMS challan system, and a couple of smart phone apps that provide real-time traffic updates. The digital ITEMS approach to traffic law enforcement improves traffic law enforcement by improving transparency with the traffic controller who records or keeps the right database of the information. To identify traffic violators, Bangalore traffic cops now use modern video technology. It might be a red light, a stop sign, rash driving, not wearing a helmet and seat belt, using a cell phone while driving, or something else. ITEMS has 2,028 body-worn cameras, 250 AI cameras that recognize license plates, and another 80 cameras that detect red light violations. The project began with ten cameras equipped with RLVD technology at the intersection, and now these new cameras equipped with an Automatic Number Plate Recognition (ANPR) system will be synchronized with the others to detect violators whether they exceeded the speed limit or jumped the signal. Every infringement is documented with five photos and a ten-second video clip by the AI. The ITEMS method prevents some road traffic accidents while also instilling safety behaviors in individuals who do not follow the laws

6.2 RLVD Systems Abroad

A total of 9,951 vehicles were involved in fatal crashes at traffic signals in 1999 and 2000 based on the Fatality Analysis Reporting System crash database, with 20% of these vehicles failing to obey the signals (Campbell et al., 2004). From 1992 to 1998, an estimated 1.5 million people were injured in crashes related to red light violation (Insurance Institute for Highway Safety, 2000). Intersections are among the most dangerous locations on U.S. roadways, and red light running is a major transportation safety challenge at signalized intersections.

This section reviews applications of automated enforcement of red-light violation systems. The section begins with a review of applications from the United States located in New York City, California, Singapore, Victoria, and Great Britain, are also reviewed the review of applications focuses on the technology being used and the results of the automated enforcement program.

Singapore

The safety impact of Red Light Runners (RLR) camera systems installed at many signalized intersections in Singapore, during a 5-year program that started in August 1986, was reported by Ng et al. (13) in 1997. At the time of the report, the authors reported that about one in five signalized intersections was covered by one to three camera systems. (This would make Singapore the highest number and density location for RLR camera systems.) The researchers undertook different crash analyses. One was designed to review the trend of crashes at 125 camera locations over several years. It was observed that there has been a nearly steady decline in average annual crashes at camera locations since 1986, when the first stage of cameras was installed. The researchers noted that this decline occurred despite a 22% growth in vehicle population and a general fatal crash trend among the population of signalized intersections. Another analysis examined the before-and-after change in crash types at the camera locations. The results of that analysis, the reductions are impressive, there is no certainty that they are due solely to the cameras.

California, United States

In enforcing red light-violations, the San Francisco Police Department issues over 15,000 citations annually one of the most widely publicized evaluations of red-light cameras was that done for Oxnard by Retting and Kyrychenko (Fleck & Smith, 2001) of the Insurance Institute of Highway Safety. Oxnard was one of the first jurisdictions in the United States to employ cameras. The authors compared the change in crashes for signalized and non-signalized intersections in four similar (with respect to size and crash frequency) California cities—Oxnard, Bakersfield, San Bernardino, and Santa Barbara. In Oxnard, RLR cameras were installed for one approach at 11 of their approximately 125 signalized intersections; enforcement began in July 1997. The other three cities, which did not have RLR cameras, were used as control sites to establish that any observed change in crashes found in Oxnard was due to the camera program and not to potentially confounding external factors. Changes in crash occurrences after RLR enforcement were compared for Oxnard and the three control cities, and for signalized as well as non-signalized intersections. In 1996, San Francisco initiated a pilot study to determine the feasibility of using automated enforcement technology to combat the problem of red-light violations.

New York City

New York City has the United States' oldest and largest automated enforcement of red-light violations programme. The initiative began in 1993 and is currently implemented at 18 intersections. Traffipax-Vertrieb, a German corporation, was responsible for the technology employed in New York City. The Robot 35-mm camera was utilised to create the system. Two loops per lane were installed on the pavement, a three-tenths of a second (0.3 sec) buffer were allowed, and the system contained a minimum speed threshold of 15 miles per hour for vehicles

to be photographed. Every camera has some wear and tear issues, but this one outperforms them all. The cameras from the winter operation showed no signs of being affected by the weather. When necessary, changes to the software used to process violations and track violation notices have been done without disturbing the operating system. Violations at junctions employing automated enforcement technology have fallen by 20% since the programme began. According to statistics from the programme, 65% of violators pay the fine after receiving the first notice of violation. New York City will improve its programme with 12 new advanced cameras in the future.

Victoria

Australia has used automated enforcement technology for red light violations since 1979. In Victoria, automated enforcement systems were installed to reduce the number of collisions occurring because of motorists running red lights. Currently, the automated enforcement program for red light violations incorporates 35 cameras that are rotated through 132 sites throughout the Melbourne metropolitan area. The technology being used in Victoria is manufactured by Gatsometer B.V. and the specific system is the Type 36 MSG. The sensor configuration of the system uses vehicle detection induction loops that are set in the pavement. The loops are placed as close as possible to the stop line, usually between the stop line and the first pedestrian crossing line. A different evaluation of the program reported that red light cameras reduced the incidents of red-light violations by 35 to 60% [1]. The same report also stated that right-angle accidents were reduced by 32%, right-angle turning accidents decreased by 25%, rear-end accidents decreased by 30.8%, and an increase in rear-end turning accidents of 28.2% occurred.

Great Britain

In West London, 1997 research installed 21 cameras and 12 red light cameras. It was discovered that the presence of speed and red-light violation cameras reduced the frequency of signal crashes by 16%, which was not statistically significant. It is likely that the presence of speed and red-light violation cameras reduced the crash frequency because people approached at a slower speed, resulting in fewer red-light runners.

Six intersections in Scotland have been fitted with a Red Light Runners (RLR) detecting camera. Red light jumping was the principal cause of 17% of crashes at signalised junctions, according to a primary analysis conducted in 1992, with a probable influence component in 8% of the crashes. According to the violation analysis, there has been a remarkable reduction of over 70% in total traffic violation cases in red-light corridors, with the violation rate dropping from 6.1% to 2.2%.

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ANNEXURE-1

Some Relevant Specifications as per existing IRC: SP: 119

Automated enforcement systems designed to detect red light violations must have the ability to detect and record violations under varying field conditions and to produce clear images that are easily retrieved and stored. The following requirements that automated enforcement systems should include:

1. The ability to capture, transmit, process, store and recover captured images so that data may be managed in an efficient manner.
2. Sufficient resolution to satisfy court standards for the image-reading of vehicle license plates, clear detail of the vehicle, and identification of the vehicle operator (if necessary).
3. The capability to prevent the spreading of over exposed portions of an image (anti-blooming) that may result from vehicle headlights or sunlight from highly reflective surfaces.
4. Adequate differentiation of light to dark areas within an image to provide necessary details (also referred to as contrast latitude).
5. The ability to provide blur-free images of moving vehicles.
6. The ability to detect at varying levels of light.
7. Image enhancement circuitry to eliminate major sensor defects such as bright or dark columns which detract from the visible presentation of an image.
8. Continuous read-out of images to support monitoring along with single fame capture capability for recognising several successive vehicles committing a violation.
9. The ability to be moved to different locations or to be mounted into a permanent position; and
10. Components should be environmentally friendly.

This ITS based solution of red light violation detection system may help reduce the accidents as it creates a sense of psychological fear among users not to violate the traffic rules . It also helps the driver to respect the law and provides visual and documentary evidences of violation and capturing regular offenders. There are three types of systems available namely Inductive Loop Sensor, above Ground Sensors like Radar and Microwave based sensors techniques and ANPR Cameras.

Inductive Loop Sensor consists of sensor loops (Inductive Type) Detection System (Single Loop and Two Loop configuration depending on system design), Video camera and still camera with flash light and controller equipment's and communication system. In the above ground sensors system, functioning is almost same as the Inductive Loop except that the system uses above ground based detection system like laser system, which makes it simple and there is no need to dig the road or reroute the traffic at the time of installation.

ANPR (Automatic Number Plate Recognisation) cameras having a combination of IR (Infra Red) and Visual Spectrum Camera are used as part of an automated Red Light enforcement program. This will enable system to perform Automatic Vehicle Identification (AVI) with the help of a central processing unit, and a storage subsystem to record information such as date, time and location. This will enable enough documentary evidence for the offenders to be booked for violation and also instil a sense of discipline for Traffic Signal in road users. This will help to reduce the junction crashes due to red light violation.

RLVD can be used for following purposes: -Automatic vehicle identification system.

- Vehicle surveillance - Vehicle and Speed Checks.
- Stolen Vehicle Detection.
- Monitoring known offenders, criminals.
- Border Patrol / Enforcement.
- Cargo Container Logistic Management System.
- Video based Red Light Violation Detection System
- Complete Evidence Capturing Mechanism
- Works with non-lane discipline traffic
- Intuitive and User-Friendly User Interface
- Data security to ensure Confidentiality and Integrity
- 24x7 Day and Night Operations
- Works seamlessly across all Weather Conditions
- Review Violation and Evidence Data
- Real Time Alerts for Red Light Violation
- Category management: Hot-listed/Stolen/VIP
- Advanced Search Options
- Customized Reports
- User Management and Admin Function

ANNEXURE 2

NHAI GUIDELINES ON RLVD SYSTEM FOR INTER URBAN ROADS

Some Guidelines as per the NHAI Specification report on Red Light Violation Systems released in August 2020:

1) System should be totally digital
2) The system shall detect and capture vehicle details when
    a) It violates the stop line/zebra crossing,
    b) It violates the red-light signal
3) System shall be non-Intrusive. It shall have the option of working without integration with traffic controllers, but ATMS Contractors should also provide undertaking that their system also works with integration of controllers.
4) Red light system shall be a completely fair system with all evidence captured before and after the red-light jumping infraction has happened.
5) Each camera system shall cover road width of 3.5 m or 7 m or 10.5 m and above.
6) The Camera specifications shall be same as specified in the VIDS section for bullet/box camera and VSDS section for ANPR camera.
7) Red light system should detect vehicle presence to act as input to control the Traffic Controller.
8) System can be a composite unit with all components inside the IP66 box or comprised of camera or other units mounted on poles or gantries with controller and processors at side poles to make sure all lanes of the road are covered.
9) System should be able to recognize the entire event by which the same can be justified automatically by fetching the number plate of cars in violation.
10) The system shall have alert generation feature as per the requirement of the Traffic Police, the same shall be finalized after discussion with the concerned enforcement agencies of the state in consultant with the ITS Engineer.
11) Certification: UL (Underwriters Laboratories), BIS (Bureau of Indian Standards) and RoHS compliant certificate.

System can be integrated with existing e-Challan generating systems with fine generated for each infraction with multiple images clearly showing colour of red-light signal and violation i.e. colour image of context camera, date, time, vehicle registration number, classification of offence etc. Image having water mark of Date & time, Place, Latitude & Longitude to be uploaded.

(The Official amendments to this document would be published by the IRC in its periodical, 'Indian Highways' which shall be considered as effective and as part of the Code/Guidelines/ Manual etc. from the date specified therein)

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